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EVOLUTION OF TECHNICAL EDUCATION

IN

ECONOMICS, POLITICS, STATECRAFT AND MORALS; THE WORK OF THE FRANKLIN INSTITUTE DURING SEVENTY-FIVE YEARS.

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[Commemorative Meeting held in Convention Hall, National Export Exposition, Saturday, October 7th, on the Occasion of the Celebration of the Seventy-fifth Anniversary of the Franklin Institute.]

The ideal education of the old Greek who would teach the youth of his country "to speak the truth and to ride a horse," although by no means as comprehensive as the "complete and perfect education" of John Milton, is at least typical of the best thought of the educator of our own time; and especially is it representative, in a way, of the ideals of the advocate of the evolution of the technical

education of people with a view to the preparation of the great body of "plain people" for "the sequel of their lives." The seeking of truths, of facts and data, and of methods of utilization of such truths in the interest of the people, in the promotion of their moral, social and intellectual advancement—of that material progress which underlies all—constitutes real education.

This constitutes a problem for the economist, for the wise political leader and for the statesman of every grade. For the ancient aristocrat and gentleman, honesty and ability to bear oneself as became a gentleman, in all out-of-door exercise as well as in social intercourse with other gentlefolk, were recognized as the fundamental elements of a proper training. Little more was then needed and little more was prescribed. As time went on, not simply the speaking of truth but the learning of truths, not simply the riding of a horse but all manly exercises and warlike accomplishments, were demanded as essential elements of the curriculum of the gentlemen. Later, as the arts of war became less exercised and as those of peace became more and more vitally important with all classes, the clergy of Europe came to dictate the form and extent of the education of the gentlemen and of the well-to-do classes of the time. Even gymnastic exercises as a part of the regular education fell into the background with the drifting out of sight of the arts of war, and the modern, monastic, gymnastic methods of education took shape and controlled all schools. Still later, after political power had fallen out of the hands of monarchs and nobles into the hands of the people, and it had come to be seen that the contemporary education was suited only to the wealthy and aristocratic classes, a new education came into existence, and Bacon and Descartes, Milton and the Marquis of Worcester and Vaucanson sought the development of this field by the introduction of systems of training of the people in such manner as would give them not only a knowledge of language and of literature, of history and of philosophy, but also an acquaintance with the sciences, pure and applied, and with the scientific bases, and even the actual processes, of those arts the prac-

tice of which must, with the great masses, occupy the entire adult and active existence.

In early historic and in prehistoric times, government, so far as developed, was simply a system of forcible control of the masses of the people with a view to the advantage of the ruler and for the purpose of securing for him means of offence and defence in his constant warfare with his neighbors. As time passed and regal power was taken from the hands of the monarch and fell into those of the aristocratic classes, the art of war was cherished largely for the same reasons as those controlling the emperors and the kings of earlier days; although the arts of peace assumed larger importance as wealth and fashion, and the always resultant luxury and effeminacy of the wealthy classes, brought into being a demand for greater intricacy of life and increasing diversification of industries; while the training of skilled workmen has constantly assumed greater and greater importance to the state. The science of economics, the true science of politics and the real and highest duty of statecraft, thus gradually came to be clearly recognized by a few great minds. Comenius and Froebel, Milton and Worcester, Descartes and Vaucanson all saw clearly the real meaning of the Greek ideal for later times, and all did what they could to introduce a broader and a better curriculum and to adapt the scheme of general education more perfectly to the needs of the people. To-day, every thoughtful and well-read and experienced educator sees that a true rendering of the Greek ideal into contemporary form would dictate the education of the people for the life and work of the people, the universal adoption of manual training in public schools, the evolution of a technical side to education, which, coupled with the older gymnastic forms, should give to every ambitious youth opportunity to learn the scientific, the logical and formal, basis of the art into which he feels himself impelled by natural predilection, and sees it should include in its range, not only all the literatures and their languages, all the sciences and their applications, and all the arts of simple accomplishment, but, even more completely and thoroughly, the

arts and vocations of common life, to the extent to which they lend themselves to scientific and logical methods of instruction. Only thus can a truly wise system of education of the people for the life and work of the people be founded.

To-day, the arts of war engage the attention of comparatively few; the arts of peace occupy practically the whole mass of the people. The chief duty of the statesman, of the wise leader in politics, as well as of the economist, is no longer primarily, almost solely, the study of war and of strategy, of diplomacy and of the raising of armies; it is now, rather, primarily and principally the promotion of the business interests of his country, the advancement of the arts of peace, the maintenance of those industries providing the essentials of modern civilizations, the diversification of industries for the purpose of giving larger opportunities and greater industrial and political independence to his own people, and the provision of that education, necessarily largely technical, which best meets the needs of the people as individuals and as a nation.

To-day, the acuteness of the political leader and the wisdom of the statesman may be very accurately gauged by the attention which he gives to the education of the people and especially to a systematic development of that technical education which has so long, but so slowly, been in process of evolution as a complement of the gymnastic, purely literary curriculum of older times. The moral and intellectual magnitude of the educator may be measured by the extent to which he has come to appreciate and to promote these evolutionary movements. The statesmen of Germany, of France, the educators of our own country, particularly, illustrate this fact. Glancing over the compilation of testimony favorable to the inauguration, in the earliest days of our republic, of a national university, as representative of a national and public scheme of education of the people, as printed by the national committee, one sees at a glance that the signatures are those of the greatest statesmen of their time; the grander his statecraft, the nobler his plans for educational development and the larger

the measure of the man in all ways. This has been true from the days of Zenophon and of Herodotus to those of Washington and of Jefferson, and of the founders of German technical education, of our "Land Grant Colleges" and of that Cornellian system which would unite in one great institution systems of education of all men in all studies; such as would prepare the scholar, equally well and with absolutely equal honor, for the rostrum, for the pulpit and for the professor's chair, the lawyer for his courts, the physician for his hospital and for ministration at the sick-bed, the engineer for construction of railroads, canals, bridges and steam-engines and steam-boats, the farmer for all forms of agriculture and the artisan for the workshop, factory and mill. Of these classes, a thousand require scientific instruction where one depends upon literature for his support; hundreds demand a knowledge of the scientific basis of the arts where one needs tuition in language; scores seek professions having a scientific foundation where one can utilize, in later life and for his own personal advantage, the "liberal" education of the so called "learned professions."

Biblical history tells us that, in the eighth generation of the race of Adam, Tubal-Cain was "the forger of every cutting instrument of brass and of iron."* The metal-working trades were thus established, necessarily, at the very beginning of civilization, and apprenticeship, which is technical education, must have become an established system before a vocation could become a trade, before the art of the individual could become the art of a guild. Life in cities could not take form until the trades of the manufacturing industries were fully organized and the age of the cities of antiquity, of ancient India, of Assyria, of Babylonia, of Asia Minor, of Egypt, Greece and Italy, measures approximately the space of time separating us from the beginnings of manual training and of trade-instruction which are, in turn, the foundations of modern technical and professional training. When the great deluge washed away the pro-

*Gen. IV, 22.

duct of the antediluvian industries, the erection of the tower of Babel was the construction, also, of a memorial to the brickmakers of the reviving world. Every modern fundamental profession, trade and vocation probably has a history approximating in its length that of the race itself. Technical education is prehistoric in source, and its history has simply been that of an originally simple and non-scientific, an empirical, system, developing by an evolution, under conditions sometimes favorable, sometimes restrictive, in such manner as to make its progress extremely variable in rate and method from its earliest to its latest phases.

George Ebers, the famous Egyptologist, and hardly less distinguished and certainly more widely known historical novelist,* finds records amid the tombs and pyramids of the valley of the Nile indicating the existence of a great school and college system supported by the Pharaohs, fifteen hundred years and more earlier than the Christian era. For the time, indeed, it was more nearly a true university system than has been seen in Europe since that era, and hardly less universal in its breadth than that inaugurated by Ezra Cornell in the United States of North America in our own generation. Organized in the "House of Seti," in Upper Thebes, it excelled the still older foundations at Heliopolis and at Memphis in its universality, and especially in its extension of its curricula into the fields of technical learning. In its preparatory school, even, were departments of theological, mathematical, legal, astronomical and pedagogical technology. Its great library contained many thousand rolls of papyrus. Schools of art, architecture, sculpture, painting and of engineering, so far as developed at the time, insured the cultivation of the æsthetic with the use ful and their union in construction. In magnitude, only Thotmes' great temple exceeded that vast pile. More than this, it was a system of free schools and colleges to which every citizen had a right to send his sons. Dormitories for the young men of the wealthier and noble classes were adjacent, and famous priests guarded and guided the pupils.

* Professor of Egyptology at the University of Leipsic.

"Scribes"—university professors, free from other labors—were given opportunity for study and research in the highest realms of science, of literature and of art, pure and applied. Its faculty numbered above 800, and there were three "prophets" appointed as directors of its colleges, of whom the high-priest was the senior. Splendid residences were assigned the faculty, and of these that of the high-priest was of unequalled magnificence.

Its successor, the "House of Rameses," was similarly but even more liberally planned, 1300 B.C. The University of Rameses was in existence 1,000 years before the foundation of the later and possibly even greater University of Alexandria.

Technical education finds its earliest, at all complete, records, in the accounts by the Greek historians of the work performed by the technical staff of the great University of Alexandria, during the centuries elapsing between the foundation of that first most complete of universities and its destruction by the Saracens.* When Hero taught mechanical engineering and Archimedes the art of war, when Hipparchus lectured on astronomy and measured the periods of planets and eclipse-cycles, and when disciples of Aristotle gave form to a logical method, technical education took on a distinct form and became recognized as an essential department of instruction. The Alexandrian university was not only the first such great educational organization, but it was, in a true sense, the first university and, for the first time—in fact, for the only time in the early history of education—an institution properly so designated, since then and there, only, in all the course of history, up to our own time, was the endeavor made to offer instruction in all the literatures, in all sciences and in all the arts of the time. Ptolemy, in its foundation, sought to provide what Ezra Cornell aspired to organize—"an institution in which any person might find instruction in any study." Aristotle and his disciples despised no fact and respected all forms of knowledge.

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* "Intellectual Development of Europe," by John W. Draper. New York: D. Appleton & Co.

The "Museum" of Alexandria was the birthplace, as Draper has truly said, of all modern science. Other nations had earlier studied natural science; other civilizations had still earlier produced great schools and great men curious in the observation and study of natural law and of nature's marvellous operations; but it was in Alexandria and in the time of the Ptolemies that we find the earliest adoption of a correct method of scientific investigation and evidences of researches to discover fact and natural law—real scientific research, "the interrogation of nature through systematically planned and prosecuted experiment."

This first and most universal of universities—the times being considered—was founded to promote the acquisition of knowledge in all fields of history, philosophy, literature and natural science, to illustrate the methods of Aristotle, the first philosopher recognizing what we are, in our conceit, prone to designate the "modern" scientific method—first seeking facts, next deducing laws, then constructing a science by the codification of the natural laws thus revealed. The older Greek "philosophy" of the imagination was rejected, and the true philosophy of fact and sound logic and scientific deduction was brought into practice. The speculative philosopher was retired and the experimental philosopher, the scientific investigator, took place in the van. Archimedes investigated the laws of hydraulics; Ptolemy those of optics; Hipparchus gave his contemporaries and his successors, even to our own time, valuable results of research in astronomy; using instruments of precision and making exact measurements as bases for his computations. Euclid created geometry and the world still finds his work perfect. Archimedes' mathematical studies gave him pre-eminence as a leader in his department, and no rival appeared for many centuries, and even up to the time of Newton. In applied sciences, in his discoveries relating to specific gravity, in his inventions of the lever, the screw, the burning mirror, apparatus of war and of peace, he proved himself the first really great producer of the mechanisms and machinery of the engineer and the physicist. Eratosthenes was the great geographer whose

work was the beginning of all that we to-day know, both as to fact and as to system; he founded physical geography. These mighty men of mind recognized the facts of the rotation of the earth, the nature of heat as a form of energy, the general distribution of light and heat, and the variations of climate throughout a spherical earth. So accurate were their astronomical measurements that Ptolemy was able to discover the moon's evection, and Hipparchus the precession of the equinoxes, measuring its period. The motions of the planets were observed and discussed, and Timocharis noted the phases and movements of Venus. Ctesibus invented fire-engines and water clocks; Hero described the first steam-engine, that form which is to-day coming in again, two thousand years after Hero, in the form of the steam-turbine, as a rival of the complicated and costly and imposing machine which is the product of an evolution having a history, as a train of mechanism, of just one century. Sosigenes of Alexandria, in the time of Julius Cæsar, went to Rome to rectify the then confused calendar, and thus this first great university, the prototype of the modern university of our own State, a university without intermediate representative in all these centuries, and which we now recognize as in fact a real and a great technical college, carried its wonderful work through the centuries immediately preceding and succeeding the Christian era.

The Saracen conquest of Egypt resulted in the destruction, in large degree, of this majestic edifice of learning; but the Saracens themselves, once the conquest was complete and they were permitted to settle down to the pursuit of the arts of peace, became inspired with the genius of investigation; the conquerors took up the work of the conquered and we now credit the Arabian philosophers and men of learning with preserving and advancing human knowledge in hardly less degree than did, in the earlier centuries, the Greek Ptolemies and their allies.

The energy of a race is like that of a river, small or great, quiet or torrential, flowing from earlier to later times, compelled by natural forces constantly to follow a general di-

rection determined by the topography of surrounding conditions, to be sure, but always forced to move on until its stock of energy is exhausted. If war demands the expenditure of this energy, it becomes destructive as a mountain torrent in time of freshet or cloud-burst; if peace supervenes, still this energy must find application, and in Egypt, after the close of the Alexandrian campaign, it fructified that intellectual domain as the Nile fertilized the valley which it traversed. Similarly, after the Greek and Roman civilization had been overwhelmed by the Goths and Vandals from the north and by the Saracens in the valley of the Nile, the Arabians diverted their talents into new and useful channels, and the flow of the stream of Saracen energies became subdued to the fructification of the whole of northern Africa and of Spain, and the development of pure and applied sciences among the Ptolemaic peoples was paralleled by that later observed among their conquerors. Destructive energy was replaced by constructive in all departments of human activity. Bagdad became a great cosmopolis in which, far more than in the metropolis of to-day, learning and scholarship and Aristotelian research were encouraged and honored. Haroun-al-Raschid instituted a school in every mosque in the whole Saracen empire, and his successor, Al-Mamum (A.D. 813–832), like the first Ptolemy, built up a great center of learning at Bagdad, collecting great libraries, calling to his court and to his colleges the men of the age, from all countries. His was the Augustan age of the Saracen empire.*

The Saracens boasted that they had produced more poets than all other nations combined; that they developed further than ever had been done before the scientific method now universal; that they substituted a study of nature, of phenomena and fact for speculation; that they promoted mathematics and the exact sciences in a previously unexampled manner; that, in their time, alchemists founded the science and the art of chemistry; that their learned men produced works on mechanics, solid and fluid,

* Draper.

optics and astronomy, geometry and trigonometry, invented algebra and adopted the Indian numeration and figures. They invented all sorts of distilling, filtering, heating and fusing apparatus, instruments of precision for the astronomer, the chemist's balance and the simpler mechanical combinations. They even constructed tables of astronomical quantities, of specific gravities and other scientific reference compilations. The library at Cairo grew to enormous dimensions and is said to have included not less than 6,500 works on astronomy alone. This was a circulating library as well as of reference. The Spanish library of the khalifs is said to have numbered 600,000 volumes, its catalogue filling forty-four volumes. It is said that a physician was compelled to refuse the invitation of a sultan, to Bokhara, because the transportation of his library would have required 400 camels. Another physician, Honian, at Bagdad, maintained a regular business of translations from other languages and issued versions of Plato, of Aristotle and of other ancient learned authors. All then known fields of knowledge and of research were cultivated, an immense literature was developed and all this without let or hindrance, without the slightest censorship on the part of the monarch. All sorts of books of reference were produced, including an "Encyclopedic Dictionary of the Sciences" by Mohammed Abu Abdallah, and colleges dotted the whole extent of the empire. Colleges were then, as now, founded by wealthy men and provided with a permanent income by endowment.* One such college, at Bagdad, with an income of 15,000 dinars, taught 6,000 students of every class, rich and poor, noble and plebeian alike. Free scholarships were provided for the needy and ample salaries for the faculty. Of these learned teachers and investigators Al-Mamum asserted: "They are the elect of God, his best and most useful servants, whose lives are devoted to the improvement of their rational faculties; the teachers of wisdom who are the true luminaries and legislators of this world, which, without their aid, would again sink into ignorance and barbarism."

* Gibbon.

Professional schools were organized; that at Cairo setting the example of stringent entrance-requirements for all who would study medicine, long before the foundation of the European school at Salerno in Italy. In all directions, in the philosophies, in the sciences, in the arts, in all industries, this fund of stored energy of the Saracen race found useful expenditure. The resulting civilization was far more lofty and admirable than was that of Europe during those and for many succeeding centuries. In fact, it was only in the fifteenth century that sufficient liberty was enjoyed by European men of science to permit them to enter freely upon that now familiar field of intellectual occupation, and it was only at the beginning of the seventeenth century, in Europe, that any really notable progress began. Since then the acceleration of the movement has been like that of a falling stone.

Technical learning and the technical and professional schools of the Saracens came into Europe mainly by way of Spain, and the Moslem conquerors of that country made famous their centuries of rule by promoting the arts and sciences in all practical ways. By the tenth century, that country had become a center of learning from which streamed, throughout the continent, the rays of scientific research and the accumulated learning of all the then existing departments of science. The practical outcome was seen in well-built, paved and lighted cities, in heating, ventilating and elaborate furnishing, on a scale and in a manner that even our own time may admire and in some respects imitate. Especially admirable were their systems of social life, with freedom from the elsewhere universal dissipation of the time, with "feasts of reason and flow of soul" in place of banquets of savage character and flow of bowl. Learned men of all countries were ever-welcome guests and Andalusia became the resort of scholars and philosophers, and of men noted for their progress in scientific research, from all countries and all nations and of every race. All were equally welcome and all alike honored. When, in the fifteenth century, the Moors were driven out of the peninsula, the Castilians found a great civilization

well established and the foundations of true learning well laid. The efforts of the anti-scientific parties of the time were never again able to entirely quench this great light; it grew steadily and pervaded not only all of Europe, but all the known world through its stimulation of research, its promotion of inventions and its application of all sciences and all arts in their thus improved state to the development of the best interests of the common people. In this vivification of the germs of our modern civilization, the Jews were particularly active and effective, and this was one of the most powerful influences leading to their later banishment. Their expulsion from Spain led to the distribution of the new civilization throughout the whole of continental Europe, wherever a Jew was admitted.

The Greeks thus carried the torch of scientific learning from their earliest days, its germ antecedent to Aristotle and Alexander by probably centuries, up to the Saracen conquest; the Arabian civilization carried it on into the fifteenth century, effectively cultivating a true philosophy of nature for at least eight hundred years; then came our own modern civilization as developed and evolved in France, Italy, Germany, Belgium, Spain and Great Britain. Its main progress has been observed during the last two or three centuries and its culmination, if culmination there be, has been observed during these last seventy-five years, since the establishment of existing systems of power-production, of transportation and of manufactures—and the inauguration of our recently developed systems of public schooling and higher scientific and technical education.

The study and investigation of mechanical science practically began in Europe with the work of that wonderfully versatile engineer, Leonardo da Vinci, whose biographies, written by men utterly ignorant of his greatest achievements, are devoted to accounts of his painting and sculpture, his verses and his travels and battles and sieges. Leonardo was the instigator of the sixteenth century renaissance of science and the technical arts and profes-

sions.* He was familiar with the Saracen literature and with their scientific work; their books and their learned men having come, by his time, into Italy and the south of France. He adopted research as the only guide in scientific matters, revived the Aristotelian and the Averroesian philosophical systems and applied these true methods to his work in applied mechanics, physics and all the natural sciences with which he, more than any other man of his day, probably, was familiar. His technical applications of the sciences were numerous and valuable and his familiarity with the literature and the science and with the learned men of his time gave currency to his productions that could not otherwise have been attained. He thus firmly founded the existing systems of thought and work in scientific and technical matters. All modern science and all contemporary workers in scientific and technical fields, whether of the schools or of the professions or in research, owe more to Leonardo than the average student can realize.

Finally came Newton and the great mathematicians, Lavoisier and the famous chemists, Boyle and the succeeding physicists, Watt and all the wonderful inventions of our century. By the end of the first quarter of this century the advancement due to all these developments was well under way and that world with which we are concerned took form.

Times have thus strangely changed in these later centuries. In the middle ages and earlier, when all the world was composed of few masters and many men, when the great body of mankind was ruled, and individuality was unknown among nations, even education was directed by the masters of men, and church and state were alike phases of aristocracy. The curriculum was prescribed by monastic rule, and the so-called "four learned professions" were theology ruled by the church, law constructed and manipulated for the monarch, medicine the refuge of younger sons of the rulers, and philosophy the resort of wealthy and aristocratic

*See particularly "Il codice Atlantico di Leonardo da Vinci." Milano. 1898.

idlers. Engineering, the first and last and always essential basis of civilization and of all true advancement in material wealth, the necessary accompaniment of advancement in learning and the promoter of the most vital moral and spiritual elevation, was unrecognized by Greek, Roman and modern European alike, during the centuries preceding the nineteenth. Great mechanics and engineers were deified in the days of mythology, but they were ignored and contemned throughout historic times until our own saw the beginning of a real renaissance of the aristocracy of ideas, of true knowledge and of noblest powers of the mind of man. Individualism and the care of the state for the individual are the practical result of the progress of our own century. The Declaration of Independence and provision for the protection of the inventor are corner-stones in the foundation of the modern and current political creed, and the firm basis of this latest and only true development of the people. It is only when each elementary atom of a population is developed to its highest and best in knowledge, intelligence, independence and character that the great mass, the nation itself, becomes strongest and best. The specific gravity of its elementary molecule is that of the mightiest mass. Give the particles weight and value, and the mass assumes maximum value as a certain consequence. A hundred years ago the schools, the colleges and the universities of even Great Britain were inaccessible to the people of England; those of the continent of Europe were reserved, practically, to aristocracy; in the newly-organized United States of America, only, of all civilized countries, was education practically and legally free to all ranks and all classes. In these United States education was, from the first, recognized as the birthright of the people.

In the Massachusetts Constitution of 1780 it was written: "The encouragement of the arts and sciences and of all literature tends to the honor of God, the advantage of the Christian religion and the benefit of this and the other United States of America." Wisdom and knowledge, as well as virtue, were recognized as essential to the prosperity of a nation, and the cultivation of the arts and sciences, as

well as of literature, was made a duty of legislatures in order that the rights and liberties of the people should be conserved. The great Northwest Territory was controlled by a primary law, the famous ordinance of 1787, in which it was declared that "Schools and the means of education shall be forever encouraged, the perfection of the individual as the elementary atom of the State being the end sought." Later came the slow but still advancing recognition of the necessities of the individual in the perfection of the school system and of the various forms of curriculum required in each grade and in each class of educational institutions. While it seems sometimes questionable whether, with our combinations of masters and of men, of corporations and of trusts, of classes and of masses, the individual is not being again deprived of that liberty and opportunity which seemed on the point of being fully insured him, it is to be noted that, in all these kaleidoscopic movements of the modern world, the individual still retains his right and his power to rise from stratum to stratum, to pass from class to class, to rise or fall, or to swerve from old into new courses, just as readily and just as far as his desires and his natural powers impel and permit. "Liberty always and everywhere insists on the use of all legitimate materials at hand for the attainment of its purposes. Such materials are ability, education, foresight, invention, personal influence and material resources."* Only individual liberty to move in any and every direction in which one's talents, tendencies, interests, proclivities lead can give true progress to individual or to nation. Freedom to secure, not simply an education, but just the sort of education that one's talents and inclinations or one's necessities may seem to call for, is one of the most vitally important of those rights which Magna Charta and the Declaration of Independence have assured to mankind. The placing of schools of engineering beside those of law and of medicine, the rehabilitation of the profession as one of the learned, as perhaps the most learned of, professions,

* "Irresistible Tendencies." President Charles Kendall Adams. *Atlantic Monthly*, September, 1899, p. 293.

the general organization of courses of instruction in the arts and sciences—sciences applied as well as "pure"—and the extension of the school and college systems over the realms of technical, trade and professional instruction and training, have been the most obvious and fruitful results of the liberty of the individual and of the endeavors of our century to promote the interests of the citizen and through him the progress of the nation.

While it is perfectly true that the evolution of education, including those branches which we distinctively call technical, covers a period extending back to the beginning of civilization, if not of human life on this globe, it is none the less true that more has been accomplished during our own century, more during the period of seventy-five years in the history of which we have here and now such special interest, than during the centuries, millenniums, which preceded.

Three remarkable developments of the present century, all the outcome of great social processes of evolution in various departments of our later civilization, have compelled the attention of students of history and of sociology in these later days; illustrating the fact that all modern progress has been made by advances of continuously increasing importance. The rate of progression under the action of the mighty forces which have become so sensible, in these decades which have seen substantially all the grandest movements of humanity, like that of a stone falling under action of gravitation, has been in each of these directions an acceleration. These three most wonderful accelerations have been: (1) the progress of invention and of the mechanic arts; (2) the evolution of modern physical sciences; (3) the advancement of systematic methods of cultivation of the mind. Progress in the mechanic arts and engineering, scientific discovery, and the construction of the sciences, and that form of intellectual training which we call education have all constituted most important characteristics of the progress of the century.

At the beginning of this century the existing educational system had not taken form, and its most striking develop-

ment, the education of a people for the life and work of a people, the supplementing of a purely—and most admirable and most desirable—gymnastic education by technical instruction and professional training in the industrial professions, had not become systematized. Especially is it the fact that the distinguishing characteristic of modern methods of education, classic and scientific, technical and professional alike—the placing of the work of instruction, in every branch of the pantology of modern educations, in the hands of specialists and of experts, of men fitted by special education, by peculiar experience, and by natural proclivities to communicate most of each special knowledge to the pupil—has only now, and even now not completely, come into the accepted platform and constitution of education. A generation ago, even, the proposition that, in education, as in all other departments of human activity, to insure success the work must be performed by the expert worker, was not admitted, and it was not unusual to place in charge of a department, or at the head of a college even, a man having no technical familiarity with the methods of the practitioner, whether mathematician or astronomer, chemist or physicist, engineer or classicist. Clergymen were given the place of the pedagogical expert; lawyers were made heads of schools of engineering; classicists were made presidents of schools of science; and the idea of finding a man fitted by practical experience and natural talent for the position only properly assigned to an expert professional was unrecognized in the general confusion attending the construction and operation of the educational system. To-day all this is changed. Clergymen control the schools of theology, lawyers take in hand the schools of law, and engineers are taking the management of the schools of engineering; and the latest and the least recognized forms of professional school are coming to be known as those exacting most of their students and adopting most extensive and intensive curricula.*

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* "Educational Problems. Electrical Engineering as a Profession." R. H. T. (Reprinted from the N. Y. Evening *Post*, September 10, 1898.)

A glance through the pages of history reveals the fundamental thought of the modern and so-called education in the spoken and written words of philosophers of all ages, and its practical embodiment in the school systems has been witnessed, in some degree, at least, from the earliest historic times. The first great university, that which even now stands, its time and surroundings being considered, as the representative university of all time, that founded by the Ptolemies over two thousand years ago, included technical learning and professional training in its curriculum, notwithstanding the anti-utilitarian sentiment of the Greek people and their philosophers and nobles. Astronomy and navigation, mechanics and engineering, mathematics and all then recognized applied sciences were there taught to all students and disciples by the most learned men of the time. The transfer of the arts and sciences and of all learning from Greece to Egypt, and by the Saracens to Spain, and from Spain and the shores of northern Africa to Europe, and through the centuries to our own times, has always been so effected as to maintain technical and professional schools as a part of the system of education of every state, and the organization of the schools at Bologna and at Salerno in connection with the medical and legal professions illustrated, centuries ago, the idea of the modern professional school. The Greek and the Roman and the Saracen and the modern European educations all alike were more than simply gymnastic and "classical;" all included more or less, in varying degree at different periods, the technical and practical side of education.

It was not, however, until the seventeenth century that special and precisely planned technical schools or departments of the university became recognized necessities in the minds of many men, and applied sciences were seen to be the real and ultimate end of the pursuit of the knowledge of the pure sciences, and the gymnastic forms of education to have an ulterior and vital purpose in the promotion of the welfare of the people. Plato had declared education to be the business of the state, and the inference was inevitable that the state should provide that education mos

likely to advantage the people. Milton pleaded for a "complete and perfect" education that should "fit a man to perform justly, skilfully and magnanimously all the offices, both private and public, of peace and war." Bacon had the same thought, and Comenius, his disciple, planned a real "university," to include in its faculty men of science learned in the applications of science in the arts as well as men learned in languages and literatures. The Marquis of Worcester, the inventor of one of the modern steam-engines, the exponent for his time of the truly broad and university-educated man, urged upon his monarch the organization of a system of technical schools for the purpose of promoting the highest interests of the nation; Descartes sought the same result in a similar manner in France, and, in that century, while all the sciences were taking new forms and making new and extraordinary progress through the then new systems of scientific research, the perfection and completing of the educational systems was a prominent thought in the minds of many of the greatest men of the day. Descartes, in fact, proposed a sort of Franklin Institute in which should be provided lectureships and schools for the people, a people's technical university—if that term, thus applied by John Scott Russell, may be admitted—in which the systematic and scientific development of all the educations likely to help the people to prepare themselves for the sequel of their lives should be effected. The foundation of the French "Conservatoire des Arts et Metiers," by the great inventor and mechanic, Vaucanson, was probably the first important actual embodiment of the ideas which had been familiar to Plato, to Aristotle, to the Ptolemies and their successors in the realm of education, in later times. Martin Luther was among these successors, and he and other great German educators early adopted the views of the leaders of thought of the preceding centuries. Germany was the first nation to put in practice the thesis of Plato and to inaugurate, formally and with considerable extent and symmetry, the systems of modern technical education of the people for the life and work of the people, and magnificently, as we may now

perceive, has that nation profited by such wisdom and practical statecraft. To-day the German system of national education is the admiration of the world. It is now a half century since John Scott Russell made his first study of those schools of the people of which he wrote in 1869 so glowing a panegyric.* They have steadily improved and broadened their field from that day to this, and are still improving and maintaining their lead over other nations in many ways, although, if we may accept the judgment of some of their own ablest educators and professional men, our own country has, during the present generation, struck on in advance of them in some departments in methods and curricula. Trotzendorf, Sturm, Neander and Comenius, Spencer and Francke, Basedort and Pestalozzi and Hecker built foundations upon which arose a great system of useful and stimulating education of every class in the community, and in such manner as should give to all the power of making the most and best of every God-given faculty, physical, intellectual and spiritual. This system revivified and regenerated the German nation much as, in these later days, the "land-grant" legislation of our own

* "Twenty years ago professional duty took me to Germany for the first time. I cannot forget my impression at the sight of whole nations growing up in the full enjoyment of systematic, organized, I might almost say perfect, education. I had already become acquainted with some theories and forms of education. I had read Plato's description of the perfect training for a nation. I was familiar with elementary school-teaching, and enjoyed the privileges of university education and the still higher education of the workshop. I was familiar with the system of Bell and Lancaster, having had personal acquaintance with its authors, and had myself taken an active part in schools of art and mechanics' institutions, but I confess to have been profoundly astonished—I may say humiliated—at the sight of nations whose rulers had chosen to undertake the systematic education of their people, and of peoples who had chosen to bear the burdens and to make the sacrifices necessary to obtain it. I do not know to what men or class of men in Germany the forethought, organization, and patriotism are to be attributed which made them lay aside personal ambition, political animosity, religious sectarianism, and state parsimony in order to unite all the classes of people in a unanimous effort to raise every rank in society to a higher condition of personal excellence and usefulness, and, by diffusing equality of education, to extinguish the most grievous of class distinctions."—"Systematic Technical Education." John Scott Russell. London. 1869.

country has inaugurated a new system and new views of the needs of the people and the duties of the state. It made evident the fact that, as Russell states the point, the education of the nation is to be divided into two distinct divisions, logically: the one, that which "educates and matures the man, and which we call 'general education;'" the other, that which "specially qualifies the citizen for fulfilling that narrow round of duties which the subdivisions of labor in civilized countries impose on the individual as his special contribution to the commonwealth and which we may call special or technical." In Germany, Russell found, as you or I may find to-day, the most systematic and economical and fruitful, the most "complete and perfect" national organization for the special care of this second division of educational work that the world has yet seen.

When, in our own country, we secure the union of this German national system of administration and this complete distribution of the statesman's care over all classes and in all localities, with our own peculiar and specially efficient system of union of the scientific with the practical, the combination of gymnastic teaching with scientific experimental methods of the laboratory, in all departments and in all technical and professional work, we shall have attained very nearly the ideal of Milton and of the great educators and the real statesmen of our own time. This must soon come. The course of modern progress in this department of national life has been practically one which has a history, as we have seen, dating back to the earliest days of Greek culture; but real progress, with acceleration of measurable degree, really began in the times of Milton and of Bacon, took on importance with the organization of the German national system of technical and professional education in connection with the older gymnastic systems, and assumed visible importance at about the time of the incorporation of the great enterprise whose accomplishments we here and now celebrate. During this century, and particularly since the last generation took a hand in the work, progress has been steady and increasingly rapid. Another generation should see our own country provided

with an educational system, perfect and complete, broad as the continent, deep as modern life and rich and fruitful as the best thought of the wisest educators and greatest statesmen can make it.

Every State and every nation owes to its people the organization of a general system of education—not abstract and ideal, not fitted to the purposes of the well-to-do citizens solely, not planned from the point of view of the older academician or fitted into the ancient monastic scheme—a system adapted to the immediate and practical needs of a great body of civilized people endeavoring to live and work and to enjoy the privileges of modern civilization, on an average income of between $600 and $700 a year for a family, in the settled portions of the country; when this is understood, the question finds easy solution—in words. The difficulties of securing the inauguration, in even our enlightened country, of such a system, in the face of long-standing prejudice, of existing and established curricula of the ancient and cloisteral type, of indifference on the part of politicians filling places belonging to statesmen, of ignorance, on the part not only of the average citizen and voter, but even on the part of the intelligent men of the country, very few of whom have given time to investigation, or thought to this most important of economical subjects, are beyond estimate. These difficulties, however, are certain to be in time overcome, for their removal is essential to the progress of our country in its great career.

The classification may, perhaps, take some such form as this:*

(*a*) A common-school system of general education providing the elementary studies of a good English education, perfecting the pupil in the arts of reading, writing and

* This scheme was substantially constructed as here presented by the writer when, as member of the New Jersey Commission for Devising a Plan for Encouragement of Manufacturing Industries in that State and, as Secretary of the Commission, he prepared for the Commission such a scheme.

See Report of New Jersey State Commission, Trenton, 1878; also *Sibley Journal of Engineering*, June, 1892; "The Demands of the State;" also the *Trans. Am. Soc. M. E.*, 1892, Vol. XIV; and *Trans. Am. Soc. for Promotion of Engineering Education*, 1898; "Organization of Engineering Courses," etc.

arithmetic, at least, and with so much of the most essential primary work in language, geography, etc., as space can be found for, without reducing the vitally important work to inefficiency. This system should be adapted to the needs of all classes.

(*b*) A system of special adaptation of primary instruction to the needs of children who must become skilled artisans and who cannot be kept in school by their parents longer than during the period of their growth to that size and age at which they can be made to assist in the support of the family. Such a system may, perhaps, prove to require special adaptation of text-books to the purpose, in which text-books the terms of the trades, and reading matter giving accounts of industrial processes, may be introduced.

(*c*) A system of trade-schools in which general and special instruction may be given pupils preparing to enter the leading industries, in which schools the principles underlying the principal vocations of the locality are to be taught and the essential actual manipulations of the trades are to be illustrated and taught by practical exercises until the pupil becomes expert.

Thus, the Germans have besprinkled all over their country schools of carpentry, blacksmithing, weaving, bleaching and dyeing, forestry, agriculture, etc.

These schools should be established in every city and town in the State.

(*d*) Polytechnic schools should be incorporated, formally and with system, into the great educational scheme of the State and of the country, in which higher work in the applied sciences and, usually, some trade or professional instruction should be offered students whose circumstances are such that they may be given an education extending toward the years of maturity and whose talents and inclinations lead them to select technical school work as introductory to their later practice of the industrial arts.

(*e*) Technical schools and colleges and professional schools within the colleges and universities, in which the highest professional instruction in the applied sciences and in the scientific basis of the profession may be offered those who

are permitted by rare good fortune to secure a good, a liberal education while preparing for entrance into the professional school and upon their chosen line of life-work.

(*f*) Such a bureaucratic system of supervision and conduct, presumably by the State, acting through experts in all branches of educational work, and all imbued with the Miltonian idea, as will insure symmetry and efficiency of the whole great structure of education of the people for the life and work of the people.

(*g*) In the United States the work of the several States should, it would seem, be correlated by a great central, a national organization, a national university, presumably, to which all lines should converge straight from the most elementary of the primary departments and schools, through the whole system of academic and technical secondary schools and State colleges and universities, and which should thus serve at once as a source of authority and of instructing talent of the loftiest character; providing men of genius and giving grandest educational advantages to all the lower grades; raising up the level to which the tide of culture may rise in attaining the highest possible altitude, and serving, further, as the ultimate goal of the great minds of the nation.

(*h*) National bureaux of education having enlarged powers, wider duties and grander opportunities of engaging in the task of instituting and promoting systematic and general education, such as Milton would have approved, and serving as the great advisory and directing agents in the permanent task of maintaining and improving the symmetry and completeness of the whole national, State and local systems of general and special education.

Supplementing all these, and doing a work that cannot be performed by any system of public teaching in classes and schools, should be found in every city and town such institutions as this in Philadelphia, lending a hand to the ambitious and less fortunate members of the body politic who have been unable to secure the advantages of systematic instruction or who, having neglected opportunities of this sort in earlier life, later are awakened to the desirability of per-

fecting and completing an imperfect and incomplete education.

The grand developments in the direction of the education of the people for the life and work of the people, in these later times, have thus far been :

(1) The institution of the system of common school education in the United States, a system unequalled even now elsewhere, giving to every citizen a preparation for a life worth living, such as no people ever had before.

(2) The organization, first in France, of great technical schools under the supervision of the government, in which the older professional methods of training are adopted in the preparation of youth for the professions of the constructive arts and engineering.

(3) The establishment by Germany, in more complete form, of a system of national schools, manual training, trade and higher technical, such as is represented, in type, by the great Prussian school at Charlottenburg, near Berlin.

(4) The organization of special, isolated, usually privately endowed, polytechnic and engineering schools, like those of the United States and Great Britain, and which are typified by our military and naval academies, the Troy Polytechnic Institute, the Massachusetts Institute of Technology, the Stevens Institute of Technology and the Drexel Institute.

(5) The development of State universities devoted, in fair proportion, to the instruction of students in technical departments and schools under the patronage and care of the State, somewhat after the manner of the common schools—a system which finds its highest development in the Middle and Western States in this country, and which forms part of the whole educational system of the State. The existence of large and privately endowed colleges and universities in the Eastern States has prevented equal development on this side the Alleghenies.

"What is wanted in our day is that complete and perfect representative of one great and all-embracing sy[illegible] which shall, for its time, do what was done by the grandest of all ancient institutions, the greatest of all the ancient

'wonders of the world,' in its day—offer to all-comers opportunity to study and to pursue all the sciences, all the literatures and all the arts of the contemporary civilization. Ezra Cornell expressed the ideas of Plato and of Aristotle and of Milton and of John Scott Russell in a sentence: 'I would found an institution in which any person can find instruction in any study.'

"This Cornellian ambition, absurd as it may seem to the dull plodder in the ways of the mediæval educator and of the monastic regime, is precisely that of the German Empire and of its constituent political elements of the earlier generations, since the time of Luther.

"Once it is recognized as a great principle of politics and economics that the primary duty of the State—given a system of government which steadily maintains the law and preserves the peace—is to see that the people are taught to make themselves competent to make the most of life and of the marvellous opportunities which modern civilization presents to all men, the obvious universality of the scheme of public education and training 'for the sequel of the lives' of citizens is instantly recognized, and its practicability in a reasonable sense as well; for the powers of the State are to be invoked to their utmost limits."*

While common schools, as we know them, were organized in the older States during the colonial period, and in the newer States with the adoption of their constitutions and the formation of their State or even of their territorial governments, it was not until about 1825 that the condition of the country, industrially and politically, had become so well settled that the attention of the people could be given without distraction to the solution of the great problems involved in their thorough organization. Since then our present universal and remarkably efficient common school education has taken shape and has come to constitute the foundation of all secondary and higher education, liberal, classical, even technical and professional. To-day, the

* "On the Organization of Engineering Courses, etc.:" "Trans. Am. Society for Promotion of Engineering Education," R. H. T.; 1898.

whole population of our country is at least educated in the common schools if not in the higher departments of our school and college system. This is the solid and enduring basis of the intellectual and social, and largely even of the moral, life of our nation.

The organization of the great technical schools of Europe, the progenitors of our own technical and industrial schools, may perhaps be properly said to have begun with the inauguration, in 1785, of the French "Conservatoire Imperial des Arts et Métiers," as it is officially called. The establishment was, in 1793, placed in the hands of a "Commission temporaire des Arts," and, still later, the present title was conferred upon it by a decree of the "Convention Nationale." The "Commission temporaire" was fortunately able to preserve the splendid collections uninjured during the disturbed period of revolution in which they had charge of them, and even procured from the Convention a decree making their charge a "depot public" and authorizing the appointment of three "demonstrateurs" and a designer to conduct a course of instruction. A little later, the whole establishment was domiciled in the old priory of Saint-Martin-des-Champs. On its faculty-lists have been numbered many of the greatest names known to France and the world—Thenard, Charles, Darcet, Dupin, Clement, Berthollet, Gay Lussac, Arago, Pouillet, Poncelet, Ollivier, Bequerel, Moll, Alcorn, Tresca, Morin and Laussedat are names familiar throughout the civilized world.

The Conservatoire was not actually constituted a school of technical instruction, however, until 1819, and it has never been a school for the workingmen of France, but has been devoted to the education of students for the higher positions in the industrial system and to the training of professional engineers.

A more typical example of the form of industrial school which is most effective in the development of manufactures and the arts is the later "École Centrale des Arts et Manufactures," founded at Paris in 1829. This school was taken in charge by the government in 1858, and has since that time formed a part of that general system of industrial

education to which France so largely owes her present position as a wealthy and prosperous nation. Students from all parts of France and from other countries as well are admitted. Although large numbers of the students are foreigners, this institution remains, as it was said by M. Morin and M. Tresca, "pour l'industrie, une des forces principales" of France.* Founded originally by an association of scientific men, which included MM. Dumas, Peclet, Olivier and others hardly less distinguished, it stood unaided nearly thirty years, and finally became one of the pillars of the state, and to-day furnishes a large proportion of the civil engineers of France.†

Other schools—as the École Polytechnique, l'École des Ponts et Chaussées at Paris, l'École des Mines at St. Étienne, and that at Alais, l'École des Arts et Métiers at Chalons, those at Aix and elsewhere, and the "Écoles Industrielles" at Mulhouse, Lyons, Lille and in other cities—aid in making the system of industrial education of France admirably perfect. These schools, with the exception of the "Écoles Industrielles," are under the direction of the state.

The trade schools are usually founded by municipal authority, and are under the direction of the city governments creating them. They fit young men to become good workmen and excellent superintendents. They are devoted peculiarly to instruction in the practical operations which constitute the trades. The "Polytechnique," which is, in a certain sense, the highest of the French technical schools, is largely, perhaps principally, a school of mathematics and of the pure allied sciences. L'École Centrale is the highest of the properly so-called industrial schools, and educates leading manufacturers and the directors of great industrial establishments.

The trade schools of Chalons, Aix and Angers were organized by a decree of December 30, 1865, for the instruc-

* "De l'Organization de l'Enseignement industriel et de l'Enseignement professionel."

† Letter from General Morin to Mr. Jas. Forrest, Secretary of the British Institution of Civil Engineering.

tion of all workers in wood and iron, and are only allowed to receive resident pupils, who are selected from among applicants for admission by a competitive examination. The German schools in which engineers or artisans are trained may be reduced to the following groups:

(1) Polytechnic or technical high schools, in which the principles and practice of engineering are taught, sometimes with the aid of a workshop, but generally without it. The graduates aspire to be managing engineers of mines, railroads, manufacturing establishments, etc., each according to his special preparation.

(2) Intermediate technical schools, subdivided into (1) general technical schools, (2) weaving schools, (3) industrial art schools. The general technical schools may be classified into (*a*) higher elementary technical schools, (*b*) secondary technical schools, (*c*) building and mining schools. The graduates of these schools expect to become foremen in shops and works, with the possibility of attaining to a manager's position.

(3) Apprenticeship schools for the training of skilled workmen.

(4) Evening schools, available for artisans. These are attended by men who during the day follow their craft. The "Fortbildungsschulen," or continuation schools, belong in this category.

(5) Trade and professional schools for women.

This classification may be still further simplified in relation to mechanical engineers, foremen and artisans, and all schools devoted to their service will fall under one of the following heads: (1) polytechnic schools, with or without workshops; (2) secondary technical schools; (3) apprenticeship schools; (4) trade schools.

For admission, the polytechnics require sometimes more than the equivalent of an American college course, as the École Polytechnique; sometimes the equivalent of a full course at the Realschule, as at the German polytechnics; sometimes, the best that the preparatory schools can give, as at the Imperial Institute of Technology at St. Petersburg. The range and severity of the requirements for

admission gradually diminish till, in the apprenticeship schools, only the rudiments of knowledge are demanded.

The "Gymnasia" in Germany are preparatory schools for the "Polytechnicum" as well as for the university; but the special preparatory schools for the former are usually the "Realschule."

In Europe, the custom has come to be almost universal to isolate the technical schools from the classical institutions and older universities. This has come about partly through the conviction that better work will be done by each class of college if allowed to work unhampered by the different methods and even the conflicting views, feelings, and traditions of the other, partly, perhaps, in consequence of their different foundations. Many able men favor each system, and the amalgamation of the university and the technical school is likely to be given faithful trial here and there on the continent, and in Great Britain perhaps still more completely; but they are to-day separately administered practically in nearly all cases. The view of the relative importance of manual and of gymnastic training of the mind which prevails generally in Europe is that, in the higher schools of technology at least, the training of the hands constitutes no part of the essential education of the engineer even, and that these schools should confine themselves entirely to the instruction of the student in the principles of his art, avoiding the practice, so far as it involves the use of the hands. It is perhaps a consequence of this belief and practice that the states of Europe have been, for years past, flooded with well-educated, untrained young aspirants for entrance into this vocation who not only have been unable to find employment, but who have, in many instances, been informed by employers that they are not wanted. It is the man who suitably unites theoretical and practical knowledge and training who is wanted and who best succeeds, in Germany no less than in the United States. The view held by so many of the higher schools of Germany and of France is that formerly inspiring the "École Polytechnique" at Paris, the first institution, working on the highest theoretical plane, produced in Europe.

Throughout Germany, technical schools and colleges, and trade schools are distributed so numerously that the visitor from the United States is not only impressed by the completeness of the system and by its universality, but is oppressed by the apprehension that his own country, unprovided with such efficient and essential means of giving to the people a good industrial education, and apparently having few citizens who understand the bearing of that fact upon the future prospects of the nation, as well as upon the character and attainments and upon the happiness and prosperity of the people, is likely to suffer severely when, in the near future, direct competition with this educated and trained nation of artisans shall produce those sad consequences against which history has over and over again warned us.

After their northern neighbors had inaugurated the new systems and methods of education, the Swiss commenced on a similar plan, and established a noble school at Zurich, where they placed some of the greatest instructors in Europe, and opened their "Polytechnicum" to the students from all parts of the world.* More than one-half the pupils are from other countries. The faculty consists of over a hundred professors, assistants and private teachers, and the number of students is above one thousand.

In Great Britain, the government and the people of that country have initiated trade schools and technical and industrial instruction in a few cities, and in connection with such institutions as King's College, the University, and the Crystal Palace Schools, in London; Owen's College, Manchester; Trinity College and others.

American schools, so far as developed in the United States, have been established, usually, by the several States, in compliance with an agreement entered into by them with the United States Government, under the terms of the Morrill Act, of 1862, the "Land Grant Bill."

Three-quarters of a century ago, the people of the United States entered upon one of those periods of renaissance in

* "Race Education." Sam'l Royce. New York, 1878.

education which, at intervals of a few years, have marked the progress of educational work in this country, and "manual labor" schools were established in many places, in which the college course of education was accompanied by a course of manual labor, either with or without compensation. A "Manual Labor Academy" was opened in 1829 at Philadelphia, which was said to be remarkably successful, the students employing their hours of rest from study in various kinds of bodily work. "Every invalid resorting to this academy in the year 1830 was restored to health."

A number of the States were provided with such schools by legislative action, and in several others, private enterprise did what the State governments had not done in this way. Among others, the Stockbridge Academy, in New Jersey, introduced this change into its program, and Gerrit Smith secured a similar arrangement for New York State at Peterboro.

A report to the House of Representatives of Pennsylvania, in 1832, indicated:

(1) That the expenses of education could thus be reduced one-half.

(2) That three hours' work per day had an important beneficial effect upon the health and strength and in promoting good spirits among students.

(3) That it had an equally useful effect upon the intellectual advancement of students.

(4) That such a system is advantageous in that it aids the impecunious student to obtain advantages in education which are ordinarily enjoyed by the rich only.

(5) That students thus trained make better citizens and more successful men than when not thus physically trained.

The Land Grant Colleges of the United States—of the several States, rather—are the product of one of the grandest examples of statesmanlike legislation that the world has yet seen—one second in importance and fruitfulness to no act of legislation subsequent to the promulgation of the Constitution of the United States. Like all great enterprises having for their purpose the benefit of the people by legislative enactment, this failed of complete success

through the indifference, the folly, or the absolute stupidity of many of those public servants to whom its operation was entrusted; it has, nevertheless, produced incalculable good, both directly, in the foundation and partial support of technical education, and indirectly, and very probably to a vastly greater extent, through its influence upon the States, inducing them to take up and carry on the work from the point at which the General Government left it. It is largely to this legislation that the foundation of the now numerous State universities is due, and the organization of the systems of State education which now more or less completely cover the whole field from primary schools to universities in a large proportion of our States, illustrating the scheme of a complete system of State education to which reference was made, and of which the outline was given in the earlier part of this discussion, more satisfactorily than anywhere else outside of Germany.

The author of the Land Grant Bill, by which colleges of the useful arts were established in every State in the Union at the date of its passage, was Justin S. Morrill, then Senator from Vermont, who introduced the Bill in 1858, and secured its passage by a small majority, only to see it vetoed by James Buchanan, then President of the United States. But the statesmen who sought thus to perpetuate the strongest safeguard of the nation, the effective education of the people, lost none of their interest or enthusiasm, and persevered in their plan, bringing the Bill before the next Congress and the next, and finally they had the satisfaction of seeing this measure become a law during the administration of Lincoln and in the midst of the dark days of the war. "The genius of Lincoln rose to the occasion. With one hand he smote off the fetters of the slave; with the other he joined in a splendid effort to subjugate nature. On the second of July, 1862, while the announcement of emancipation was still on his desk, he signed the Act of Congress donating public lands for the establishment of colleges of agriculture and the mechanic arts."

In most cases the States complied fully with the terms of the Act—some of them more than completely. In the

majority of the States the funds were invested in either State bonds or in a special bond made out for this particular purpose by the State and deposited in its treasury, and the returns were either the prescribed 5 per cent. or something more, in every case except that of the State of New York, which latter State never, until compelled by the courts, complied either in letter or in spirit with the law. Maine and Indiana paid 5 per cent.; New Hampshire, Vermont, Pennsylvania, North and South Carolina and Ohio paid 6, the funds being paid into their treasuries. Massachusetts was the only State in which the fund was divided, most of the State legislatures deciding at once and unhesitatingly that it would be better to hold the fund undivided and to either give it to some existing institution which should comply with the provisions of the grant, or founding an institution, as Cornell University, in the State of New York, in direct compliance with the terms of the law.

The following is a summary of the contributions made to the cause of "education of the people by the people for the people" from the earlier days of the Republic:*

(1) Lands by the township, under Acts of 1787 and 1800, amounting to over 1,000,000 acres, for the support of State universities.

(2) A considerable but unascertained proportion of the money surplus of $28,000,000 distributed to the States in 1836 and never recalled.

(3) A portion of the $3,500,000 constituting the share of education in the total proceeds of land-sales under the Percentage Acts of 1841 and later.

(4) A portion of the 3,500,000 acres accorded by different States to education out of the 9,500,000 acres given by Congress in 1841 for internal improvements.

(5) Further important sums not definitely known, from the sale of over 50,000,000 acres of swamp lands disposed of under provisions of the Act of 1850, from which source

* Blackmar's Report, of 1890, to the Bureau of Education. Hoyt's Report, of 1892, to the Senate Committee on a National University. Thurston's "Technical Education in the United States," "Trans. A. S. M. E.," 1893.

alone the University of California is said to have derived important aid.

(6) Revenues in a number of States from the sale of saline lands, with appropriations thereof to the support of colleges of agriculture and the mechanic arts.

(7) The more than $15,000,000 already derived from the lands accorded to States by the Act of July 2, 1862, for the support of colleges and the mechanic arts; which grant has resulted not only in the establishment of many important technical institutions, but also at the same time in such strengthening of the State universities that some of them are thus early taking their places in the foreground of the great university field.

(8) The appropriation by Act of March 2, 1887, of $15,000 per annum to each State for experimental purposes in aid of scientific agriculture in the broadest sense of that term, a yet further incidental reinforcement of the many State universities.*

(9) The aggregate of over $20,000,000 appropriated for the support of the Military Academy at West Point and the Naval Academy at Annapolis.

(10) The establishment, equipment and support of the Naval Observatory and the purely scientific bureaus of the Government at Washington.

(11) The large sums of money appropriated for the convenience and support of the Congressional and departmental libraries.

(12) The hundreds of thousands expended in buildings for the scientific museums of the Government, and the more than $3,000,000 a year so wisely granted for their support.

Since the date of this report, the nation and various States have annually added hundreds of thousands of dollars to these great sums.

Of the now famous special schools, our U. S. Military

* The State of New York, as stated in the message of the Governor, for 1892–93, taught in the public schools 1,073,093 children in the year 1892, and 772,426 were either educated in private schools or were not taught at all. The State expended in this work $21,134,516, which was $865,000 more than was paid out, on the same account, in 1891.

Academy was the first to take form, founded as it was in 1802; the Naval Academy was organized in 1845 and both have sustained a high reputation for the excellence of their curricula and the high scholarship of their graduates. The first of the independent schools privately endowed was the Rensselaer Polytechnic Institute, at Troy, N. Y., and its success led to the organization of many other schools of engineering in the succeeding generation. The Lawrence Scientific School was attached to Harvard University in 1847; the Department of Civil Engineering of the University of Michigan was organized in 1852; the Sheffield Scientific School was organized at Yale University in 1847, though much earlier proposed. The Massachusetts Institute of Technology was founded in 1864; Dartmouth College organized its technical departments in 1851 and the Thayer School in 1867. The Worcester Polytechnic Institute took form in 1868 and the Columbia College School of Mines in 1863. Peter Cooper founded the Cooper Institute in 1854 as a mixed educational and trade school and especially for the benefit of artisans and others unable to attend regularly the common and technical schools of regular curricula. The Stevens Institute of Technology (1871) organized as the first American school distinctively and especially devoted to the professional training of mechanical engineers and for the first time recognized that branch of engineering as a profession. The Towne Scientific School of the University of Pennsylvania and the technical departments of Cornell University were organized in 1868, and about 1885 the latter became recognized as colleges under the university organization. Since 1870, there have been almost annually organized and endowed schools of manual training, trade schools and polytechnic and professional engineering schools, until to-day every great city is provided with one or more. Philadelphia and Chicago are peculiarly fortunate in this respect. Nearly every large college or university has nominally, if not actually, professional and technical schools incorporated into its organization and the majority are doing admirable work in these directions. There are, to-day, about 100 reputable technical

and engineering schools in the United States and they annually graduate about 1,000 students into the constructive professions.

The Franklin Institute of the State of Pennsylvania, in its work of promotion of the mechanic arts, has taken no small part in the development of these modern systems of evolution of the Miltonian idea. During the seventy-five years which have, to date, measured its period of useful life it has performed an enormous amount of helpful work in a variety of ways.* Its endeavors have always been effective in the union of science with practice; its membership has always included men of science and men of business, educators and philosophers and great mechanics; its work has always been carried on in fields of applied science with every apparatus of instruction, schools, lectures, systems of research, exhibitions of invention and construction, and all methods of promotion of technical training of young and old, learned and unlearned. The names of Ronaldson, Cresson, Rogers, the Merricks and the Sellers, of Bache and Morton and Wilson, Tatham, Heyl and Sartain, of Jones and Longstreth and Norris and Trautwine and Houston, and many others familiar to the world, have adorned a catalogue of officers and members such as perhaps can hardly be paralleled in any other State or in any other country.

The Institute has established and has carried on all these decades technical lectures, drawing schools, even a high school for a time; it has gathered together a very extensive, unique and valuable technical *free* library and has even published scientific and practical treatises, either officially or indirectly; it has printed, for now over seventy years, its *Journal of the Franklin Institute*, complete files of which have been probably more extensively and for a longer time maintained in the libraries and technical institutions of this country and of Europe than have been those of any other existing publication of its sort on either side the Atlantic.

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* For a detailed account of its work, see "A Sketch of its Organization and History," by Dr. Wm. H. Wahl, Secretary of the Institute; published by the Institute, 1895.

It has even longer maintained a "Committee on Science and the Arts," empowered to examine and report on inventions and advances in the mechanic arts and applied sciences. The files of the *Journal* are rich in contributions of useful and extensively important matter from this committee. Medals and premiums have been offered and awarded for great inventions and improvements in the arts and in mechanisms, and the careful investigation of claims and the selection of worthy objects of such honors by the representatives of the Institute has been of immense assistance in the promotion of the highest material interests of our country. These gratuitous services have never been and can never be adequately appreciated or recognized. These committees and the *Journal* have always been under careful surveillance by the best men of city and State. The editorship of the *Journal* has illustrated this fact, for its list contains the names of Dr. Thos. P. Jones, Alexander Dallas Bache, C. B. Trego, Profs. John F. Frazer, Henry Morton and Geo. F. Barker, Robert Briggs, and two periods of service are assigned to Dr. Wm. H. Wahl, the present Secretary and editor. The Committee on Publication, always supervising the work with conscientious care, has consisted, also, of the best men in the membership of the Institute. It may well be doubted if any journal in the world has a richer list of technical contributions.

The great exhibition of American manufactures of 1824 and its successors have had an immense influence in the improvement of all the arts and manufactures of our country. In that of 1874 more than 200 silver and over 220 bronze medals and 650 diplomas were awarded to as many deserving products of American invention and skill. The electrical exhibition of 1884 probably did more to show what were the prospects of the then infant industry than any other incident or influence of the time. It was the first of its kind, and gave a prodigious impetus to that vocation and those many industries which are to-day grouped within the special field of electrical engineering. The greatest men of science, the most famous mechanics and the ablest manufacturers of mechanism found there attractions and

impressive novelties that had hitherto been to them almost undreamed of. A National Conference of Electricians, then necessarily mainly composed of physicists—for this branch of mechanical engineering had not then taken form as a department of construction or a division of the profession of engineering—was organized, and the officers of the exhibition and this congress, together, laid the foundations of the vast structure now constituting such an imposing division of our industrial system.

Researches like those described in the report of the committee organized to investigate the theory and practice of hydraulic motor construction, in the report on steam-boiler explosions, still an engineer's classic, and in that of the committee investigating the strength of the materials of construction, were at once useful and impressive. A Weather Bureau, even, was organized in 1843, and the later State weather-service and that of the United States may be fairly claimed to have grown out of that first work of this kind. The now universal system of standard screw-threads was the product of the studies of another committee, and the later investigations of water-supply for the city of Philadelphia, of the efficiencies of dynamo-electric machines and of the duration and efficiency of electric lamps, have continued the early-established practice of the Institute into our own time.

All this enormous amount of work in the promotion of the useful arts and applied sciences has been the voluntary service of able men, and not a dollar has been expended for their precious and invaluable time and thought and labor. It may well be doubted whether the history of any country or of any institution gives nobler exemplification of true patriotism.

The work of this now famous institution has not been simply, however, in the departments which have been mentioned; it has done a great work in aiding other enterprises. For a century and more this country, following the lead of its great statesmen of the days of the Revolution and of the early period of our existence as a nation, adopting the principles so admirably expressed by Hamilton and sus

tained by Washington, Jefferson and all their immediate successors, has made the promotion of the industrial arts a primary business in legislation and through executive action. This policy has borne fruit in the institution of a remarkably effective system of patent-law, in the organization of all the essential manufacturing industries and in the advancement of agriculture, directly and indirectly; supplying a home market for its products and giving it machinery which harvests its grain at ten times the rate usual seventy-five years ago, which transports it a thousand miles at less cost to the owner than then for a day's journey to market, and which opens the most distant lands of the trans-Mississippi region to settlement by the sons of the original thirteen States. In this work the Franklin Institute has taken part, and in no manner more effectively than in the inauguration of exhibitions of the products of industry, in the assistance in many ways of the managers of the great International Exhibition of 1876, and the promotion, jointly with the Philadelphia Commercial Museum, of the admirable Philadelphia Exposition of 1899.

The outcome of the policy of Hamilton has been the successful construction of a great system of domestic industries which, now that it has reached its period of maturity, is not only capable of supplying to our own people the cheapest products, the best products and the most abundant, but is also at the same time making compensation to its working people in the highest wages paid in the world, giving them the means of buying more of the comforts and the luxuries of modern life than any other people, while extending the market for the product of each industry and of each producer by making it possible for the members of every craft, and for every individual earning wages, to buy of every other producer. The fact that it is mainly by the payment of high wages to the wage-earner that a market can be made for every product at best advantage has never before in the history of the world been so well illustrated. In this great work of promotion of the whole system of American industries, Pennsylvania, and especially Philadelphia, and particularly the Franklin Institute, has had

efficient part, and the possibility of that novelty—most astounding to the disciples of Cobden and to the practitioners of the Hamiltonian method as well—has arisen from this most successful and well-sustained work of the nineteenth century in our country. An "Export Exposition" in the United States, at the end of a century of, on the whole, steady and consistent support of the policy of upbuilding and maintenance of home industries, is a lesson to the world and one which economists of the ancient sort may well study with profit. Free institutions, the patent system, the protection of domestic trade and manufactures, the consequent growth of the industrial arts, and of manufactures, the resultant provision of a market for the agriculturist, the marvellous stimulation of invention, the growth of a people in intelligence, ambition, productivity and prosperity, which have all come of the enlightened policy of the founders of the nation, are admirably illustrated at this great exposition, the crowning glory of the Franklin Institute and of the merchants of Philadelphia, and may well astonish the world.

Thus the "Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts" continues, after seventy-five years of good work, to do its noble duty more effectively each year. May the work so well begun in our century continue with increasing efficiency for centuries still to come!

THE MODERN WARSHIP,

AS COMBINING IN ITSELF THE HIGHEST RESULTS OF SKILL, INGENUITY AND SCIENTIFIC KNOWLEDGE.

BY REAR-ADMIRAL GEORGE W. MELVILLE,
Engineer-in-Chief, U. S. Navy.

[An address delivered in Convention Hall, National Export Exposition, Saturday, October 7, 1899, on the Occasion of the Celebration of the Seventy-fifth Anniversary of the Franklin Institute.]

Mr. President, Ladies and Gentlemen:

Before proceeding to discuss the subject which has been assigned me, I desire to express the great pleasure I feel in being with you on this important occasion, celebrating as it does the foundation of an institution which has done so much for the advancement of engineering and the mechanic arts. As one whose whole life from boyhood has been spent in connection with one of the branches of engineering, I feel an especial pleasure at being permitted to assist in this celebration. I want also to express my high appreciation of the honor which has been paid me in asking me to be one of the speakers. I do so with added pleasure from the fact that a great deal of the work with which I have been specially associated has been constructed here in your own city, and by men much of whose training in many cases has been due to the Franklin Institute.

The subject which has been assigned me is one of the greatest interest to an engineer, for the modern warship is the complete fruition and triumph of so many branches of the great science of engineering. Although in the ultimate analysis we owe everything to nature, we may well say that in the old wooden ships propelled by sails a very large proportion was due almost directly to nature, with only a minor part played by the artisan and the engineer; while in the modern ship, nature's part is strictly confined to the crudest of raw materials, and the finished product represents, as the title of my remarks so well expresses, the

highest development of skill, ingenuity and science in engineering and the mechanic arts.

Under the circumstances of this discussion, we may be pardoned if, in a retrospective consideration of the subject, we limit our review to steam vessels, for the reason, as I have already remarked, that the part of the engineer (using that term in its broad sense) in the old sailing vessels was exceedingly limited. We shall, by contrast, be enabled to appreciate more fully the wonderful entity which we call the modern warship, if we consider the first one.

It will interest you all very much, I am sure, to know that the first steam war vessel in the world was built for our navy, and was designed by Robert Fulton, who first made steam navigation at all practicable; and the construction of this vessel antedated the founding of this Institute only about ten years. This first vessel was called the "Demologos," or "Fulton the First," and while of what would now be considered very small dimensions, was, nevertheless, a wonder of the period. She was 156 feet long, 56 feet beam and 20 feet deep, measuring 2,475 tons, having a single water-wheel in a central well, and capable of steaming about six knots. The battery comprised twenty guns of the largest size at that date, a number of them having been taken from a captured British vessel. The hull, of course, was of wood, and the boilers were of copper. She was not completed until just after the termination of the War of 1812, so that she never saw any active service, and was blown up by an explosion of her magazine in 1829.

The next steam war vessel, also called the "Fulton," and completed in 1837, was somewhat longer than the first "Fulton," but with less beam, and proved a very successful ship for the period, being capable of steaming twelve knots per hour under favorable conditions. A most interesting thing in connection with this old vessel is the fact that the engineer who designed her machinery and superintended its erection became her chief engineer when she was commissioned, and thereby became the first engineer in the United States Navy. This distinguished gentleman is still alive and in the active practice of his profession. Doubt-

less many of you will at once know that I can only refer to Mr. Charles H. Haswell, known to every mechanic in the United States as the author of "Haswell's Pocketbook." I think we may all take great pleasure in the thought that this venerable and distinguished gentleman, who is not only the Nestor of our profession, but one of its chief ornaments, has been spared to see the growth of the war vessel from the original "Demologos" to our "Oregon" and "Minneapolis," and the merchant steamer, from the original "Clermont" to the "St. Louis" and the "Campania."

After the building of the "Fulton," steam vessels were added to the navy at regular intervals, each class marking an improvement on the preceding ones, until shortly before the commencement of our Civil War we had a class of fine frigates, which in ordnance, machinery and hull were justly considered the finest in the world.

The necessities of the Civil War, of course, gave a tremendous impetus to naval construction, and at this period we have the beginning of the evolution of the modern war vessel. In engineering, as applied to machinery and hulls, several names stand out preëminent at this period, and as strictly germane to my theme I may mention the work of two of them. The Engineer-in-Chief of the Navy during this period was Commodore Benjamin F. Isherwood, an engineer whose practical skill, ability as a designer and high scientific attainments have never been surpassed. One of the problems which he had to solve was the construction of machinery which should be thoroughly trustworthy in the hands of men of very limited experience. This led him, contrary to what would ordinarily be considered good designing, but which, under the circumstances, in my opinion, was consummate engineering skill, to build machinery very heavy, but which, as a matter of fact, never broke down and which carried our guns to victory. In those days, just as in our own, the "man behind the gun" may be most in evidence, but without the "man behind the shovel" he would never have been able to get within range of the enemy.

The destructive career of the "Alabama" had led our

authorities to decide upon the construction of a class of vessels which should be faster than any others afloat, in order that these commerce destroyers might be hunted down and themselves meet the fate which they had so often dealt out to others. Here, again, Isherwood's consummate skill and mastery of his profession showed itself. The material of the hulls was still wood, which gave a platform for the machinery altogether too flexible to permit of the type of engines which we now use; consequently he designed what were known as geared engines, which he, better than any one else, knew were extremely heavy, but the great point is that they enabled him to accomplish exactly what he set out to do. The "Wampanoag," the first of these vessels, in 1868 made the unprecedented record of nearly seventeen knots for thirty-six hours in a rough sea, and for several periods of six hours, seventeen and one-half knots. At that time no other vessel in the world, either war or merchant steamer, approached this speed within three knots.

About this time Mr. Isherwood conducted a number of experiments in connection with the expansion of steam, and boldly enunciated principles which the rest of the engineering world in many cases denounced as erroneous, but which are now accepted as fundamental facts in thermodynamics. This is notably the case with respect to cylinder condensation, as to which he was the first to enunciate the true principle.

Another great engineer became famous at this time, although he had been doing splendid work and helping to develop the war vessel before, namely, Captain John Ericsson. You all know the story of the first monitor, and it is not necessary for me to repeat it. I only wish to remark as apropos of my theme that here was a vessel which in hull, machinery and ordnance was the work of engineers, and which for that period represented the highest embodiment of engineering skill and talent. It is worth noting in this connection that the success of the "Monitor" in her engagement with the "Merrimac" was due almost entirely to the skill of her engineers, Stimers and Newton. They were

thoroughly familiar with every detail of her machinery, which needed skill to keep it in good order, and, as is well known, after the accident to the gallant commander, Worden, Stimers fought the guns while Lieutenant Greene, the executive officer, took command in the conning tower.

I must not neglect to state that splendid work during this period was done for our ordnance; and the development of this branch of engineering, largely due to the skill and ingenuity of Admiral Dahlgren, was such that at the end of the Civil War our naval guns were recognized as the best in the world.

There now comes a period in our naval history which, as far as actual results are concerned, may just as well be passed over, for while our designers were keeping abreast of the times, we were not building anything new in either ships, guns or machinery. Beginning with 1883, however, a new era dawned for the navy and we began the building of our White Squadron, which has so appropriately been termed the "New Navy," and in connection with these new ships I shall endeavor to go into some details which will thoroughly prove the correctness of the theme which has been given me to discuss.

What is the problem that confronts the naval designer? The maximum of offense, combined also with the maximum of defense, and with a maximum of mobility. It is important to note the limitation upon the naval designer as regards one vital element, namely, weight, for this has far-reaching effects in every feature of design, and differentiates in a most marked way his work from that of a designer of somewhat similar works for use on shore.

While it has been aptly said that the war vessel is a "gun platform," and it would therefore almost seem that everything else must be subordinated to securing a maximum gun fire, the vessel must be prepared to withstand an attack of an opponent of equal force, which necessitates close attention to the defensive elements. Now, under the very best circumstances, the weight of the bare hull will approach 50 per cent. of the entire displacement, which, as you know, simply means the weight of the completed ship

with everything on board, so that we have left only somewhat more than half of the displacement for guns, armor, ammunition, machinery, coal and stores. The first problem then is to construct a hull which shall safely carry all the weights, and do so with a minimum amount of material. This is a problem where the skill and ingenuity of the static engineer, for such the naval architect really is, has great room for exercise, and we see it carried out in the disposition of material in shapes which both theory and practice have shown to give the greatest strength for least weight. We see it also in the careful arrangement of frames, keelsons, longitudinal and transverse bulkheads, plating and deck stringers, while the protective deck (popularly supposed to be only for keeping out projectiles) also becomes in the hands of a skilful designer an important element of strength.

The ship must also be unsinkable, or at least as nearly so as possible, and this has led to the subdivision into water-tight compartments, and great ingenuity has been displayed in devising schemes for water-tight doors, which are absolutely necessary to give access from one compartment to another, but which, unless very carefully designed and constructed, may in time of need be a source of danger instead of safety. The latest developments in protection against submersion have taken the form of a belt of cellulose, a material which, when perforated by shot and exposed to water, immediately swells up and excludes a further inrush of water.

Great skill and ingenuity must also be displayed in the proper adjustment of weights to secure correct trim, and this, in connection with the form of the ship, must be such as to give ample stability, combined with steadiness of gun platform. This is an instance where the modern war vessel is a vast improvement on those of years ago, when the question whether a ship would be an easy or a hard roller was almost entirely a matter of luck. Now it is a matter of calculation and design, and the skilful naval architect is able to guarantee a vessel which will withstand any storm, be comfortable as regards motion, and provide a steady platform for the guns.

We may also note in this connection that the modern vessel is a striking example of what ingenuity and skill can do to make habitable and comfortable, compartments that are at best meager and crowded. We ordinarily consider light, water and air as synonymous with what is free and obtainable without effort, yet on the modern war vessel all these elements are due to the skill of the engineer. In place of the tallow candle of our forefathers, we have the electric light; in place of the casks of water many days old and far from palatable, we have absolutely pure and sparkling distilled water—this distilled water has contributed enormously to the excellent health of our crews, as was brought to the public attention in a most marked way during our recent war with Spain, when the crews of our naval vessels had hardly a man on the sick list, while the armies had enormous numbers ineffective. With its numerous bulkheads dividing it into small compartments, the modern war vessel can have no natural circulation of air, and the engineer provides pure air by artificial means. Steam radiators also make both officers and men comfortable in any kind of weather.

As a final item in connection with this branch of the subject, we may mention the remarkable development of scientific knowledge, ingenuity and skill in the prediction and determination of powers and speeds for large vessels from experiments on small wax models. Here we have combined the work of the mathematician and the physicist in working out the laws and formula involved, and the skill of the engineer and mechanician in the design and manipulation of the apparatus.

Turning now to the question of guns and armor, we have a most marked illustration of the accuracy of our theme. At the close of the Civil War our guns were still principally cast-iron smooth-bores. Progress has changed all this into the modern high-powered steel breech-loading rifle, weighing many tons, and driving at immense velocity a projectile whose encounter with an obstacle may be truly likened to that of one of Jove's thunderbolts. The stress coming upon the metal in one of these guns is as great as can possibly

be allowed with safety, and the demands for greater powers have called for all the skill of the metallurgist, combined with the ingenuity and talent of the engineer, in so disposing the metal as to get maximum results with minimum weights. The latest development in these guns, consisting of what is known as the "wire-wound gun," is extremely interesting, as showing how a form of construction, which, at first sight, might seem anything but the best, is nevertheless the disposition of the material which theory shows is most desirable, and practice thoroughly confirms.

It will, doubtless, interest you to hear a few figures of the performance of some of these great guns. The latest authorities state that a 12·5-inch breech-loading rifle, 50 calibers long, and weighing 83 tons, will propel a shell weighing 880 pounds, by a powder charge of 624 pounds, at a velocity of over 2,620 feet per second, giving an energy at the muzzle of over 40,000 foot-tons, capable of penetrating at the muzzle over 45 inches of iron. This energy means that one of our battleships of about 12,000 tons displacement, and which could carry four of these guns, would at a single discharge develop a power sufficient to lift her bodily nearly 15 feet. It can readily be imagined, therefore, what the effect of a projectile from one of these guns would be when striking another vessel at close range.

It is an extremely interesting story to read of what has been appropriately styled the "duel between guns and armor." As fast as one is improved so that its victory over the other seems assured, some inventor comes to the front with an improvement in the latter, which for a time puts it ahead. The armor on our monitors during the Civil War consisted simply of a number of 1-inch plates bolted together. At the present day, a modern projectile would go through such armor as easily as a bullet penetrates pine boards, but long ago it was discovered that a given thickness of armor was much more efficient if rolled in a solid plate, and this was developed until some of the older English battleships had iron armor as thick as 24 inches. The development of the gun soon showed that it was impossible to keep pace with it by mere additions to the thickness of the simple armor,

for a point was quickly reached where it was impossible to carry the necessary weight of armor that would be thick enough. Then came the use of special plates, the compound armor, where a hard face to break up the projectile was welded to a softer back to give the necessary strength. This was followed by steel armor, and then by the well-known Harvey process, which resembled the compound armor in having a hard face with a softer back, but where the plates were made from a single ingot without any welding. The Harvey process enabled an enormously greater resistance to be obtained with a given weight of armor, but even it has been surpassed by the Krupp process, which enables 12 inches thickness to give the same resistance as 15 of Harveyized plates.

In connection with armor plates great skill and ingenuity has been necessary to provide for giving them the proper shape and for enabling necessary machine work to be done on them after they are in position, inasmuch as the hardening process makes it practically impossible to do any work on the face of the finished plates with ordinary tools. Here an application of electricity for giving a local annealing where it was necessary to work with tools enabled the solution of this problem.

The work of the artillerist is not confined to the design and manufacture of the guns and armor alone, but the gun carriages are also important features of his work, and here there has been a great display of skill and ingenuity in devising means for the ready manipulation of these ponderous masses, and the control of the recoil due to the enormous development of energy when the gun is discharged. This is true both of the manipulation by hand and the control of the turntables, or turrets, for the larger guns, and the ease with which a turret and its contained guns, weighing several hundred tons, can be controlled by the movement of a single lever so that the pointing of the gun is almost as simple as that of an ordinary musket, is really surprising.

The chemist also has had an important part to play in connection with ordnance work, in the development of powders which would enable the enormous energy necessary to

be developed with safety to the structure of the gun. With the powder used during our Civil War it would be impossible to get the results of to-day. The development has been through what were known as slow-burning powders down to the smokeless powder of the present, where the saltpetre and charcoal of our ancestors have been displaced by the combination resulting from the treatment of cotton with nitric acid. The difference in the energy of the ordinary slow-burning powder and of the smokeless powder now used can be seen by consulting any table where the two are compared. One which I recently examined showed that guns, otherwise practically identical, required with the same weight of projectile three times the weight of ordinary powder to get the same velocity as with smokeless powder.

We must not forget, while discussing ordnance, the remarkable development of what are known as "quick-firing guns." This, as you know, is really the adaptation to large guns of the kind of ammunition and breech mechanism used on the modern small arms, and it has been carried so far that quick-firing guns are now made of as large caliber as 8-inch, giving a muzzle energy of over 10,000 foot-tons, while the number of times the gun can be discharged in a given interval is about double that of the ordinary breech loader. In the smaller sizes of these quick-firing guns the rapidity of fire is almost incredible, and I remember being particularly struck by the results of repeated trials, showing that it was possible from a six-pounder to have five projectiles in the air at once.

More than a quarter of a century ago what are known as machine guns were introduced; that is, weapons of small caliber approximating to that of ordinary small arms and slightly larger, were so arranged that the ammunition could be fed almost continuously and the rapidity of fire be so great that a single weapon would be equal to a company of soldiers. As you are doubtless aware, the Gatling gun was the earliest of these. These, too, have been developed during the intervening years, until it would seem that finality has almost been reached in the Maxim gun, where, when once started, it continues to discharge itself by the effect

of its own recoil, until the old figure of "iron rain and leaden hail" becomes a simple matter of fact. The Maxim gun will fire 600 shots per minute from a caliber of 0·45 inch or less.

We come now to the machinery of the modern vessel, and I trust that you will pardon me if I go into greater detail here, because this is my own special field and one in which it has been my lot to have been intimately associated with the construction of our new fleet. Here, more than almost anywhere else in the war vessel, the constant demand has been for greater power on less weight, and at the same time the demand has also been for thoroughly reliable machinery that would also be economical.

Progress has been so rapid that it sometimes seems that we hardly have time to get out a design as nearly perfect as possible and see it thoroughly tested in service before improvements have been suggested that render what appeared so perfect relatively obsolete.

Shortly before I became Engineer-in-Chief of the Navy, forced draught had been re-introduced, after many years of disuse. This at once gave an enormous increase of boiler power with a very slight increase of weight, due to the burning of a much larger amount of coal on a given grate surface. The shell boiler was developed until its design seemed nearly perfect, but we were confronted with the problem of getting plates sufficiently thick to withstand the increasing steam pressures in the large boilers and still be able to properly work the plates in our shops. The weight of these boilers was always very great for the power developed, and in the large sizes which they had reached, the utmost skill was necessary for their proper care and maintenance. Shortly before the time had come when further progress with the shell boiler seemed impossible, the water-tube boiler was developed to such a point that it gave us the necessary solution of the problem, and it now seems quite certain that, for some time to come at least, the boiler problem has resolved itself into a determination of the best form of water-tube boiler, inasmuch as we are sure we can construct boilers which will withstand any pressures

that are likely to be used and which are satisfactory in every other respect. These boilers offer almost absolute safety against disastrous explosion, afford a great reduction in weight, and are built to withstand comparatively rough treatment as far as heat is concerned, thus giving freedom from such troubles as leaky tubes and leaky seams, to which large shell boilers were very liable.

The demand for reduction of weights in the engines has been met by the use of stronger materials, and also their disposition in shapes where a given weight of material offers the greatest resistance. We thus have steel castings to replace cast iron; hollow forgings of oil-tempered steel, and the use of bronzes of double the strength of the older compositions. Besides the greater strength of the materials, just as important an item is their much greater reliability. Our manufacturers to-day can furnish us with forgings as to which we know that the results obtained on test pieces will be absolutely true of every part of the whole mass.

Weights have also been greatly reduced by using engines which run at much greater speeds than formerly obtained. This seems a sufficiently simple matter, and yet it was not possible until the improvement came in materials, combined with an accurate scientific knowledge of some of the questions confronting the marine engineer, which had formerly been solved almost by rule of thumb. This is notably the case with propeller design, for it was the mistaken notions on this point that really held down the engine speeds. Inasmuch as the whole office of the motive machinery is to turn the propellers, it might seem that it would be necessary to design the propeller first and make every thing else to suit it; but fortunately, now that we have accurate scientific knowledge of the conditions governing propeller design, we know that the propeller can be arranged to suit almost any speeds found desirable for the engines, and this enables us to choose engine speeds which will give us both lighter and more economical ones than were possible in olden days.

A problem in the design of engines for war vessels, which

is of considerable difficulty, and the solution of which is not yet thoroughly satisfactory, is that of securing economical results at ordinary cruising speeds, with the capacity for the power necessary at maximum speeds. As you are doubtless aware, the power necessary to drive a vessel varies approximately as the cube of the speed, so that if, as is ordinarily the case, the cruising speed is about half the maximum, the power to be developed is one eighth or less of the maximum. As was very cleverly expressed by one of my former assistants (Professor Hollis) some years ago, the problem is like that of having a beast of burden whose maximum power will be that of an elephant, but whose appetite is so adjustable that he could be economically used for work which could be performed by a donkey. You well know that an elephant would eat about the same whatever work he was doing, and while this is not exactly true of a steam engine, it nevertheless is true that its economy, when worked at powers which are so small a percentage of the maximum, is very much reduced. In some of our ships we have tried to solve this by arranging two sets of engines on each shaft, so that at the moderate powers the forward set can be uncoupled. The ill-fated "Maine" had an arrangement whereby the large cylinders of her triple expansion engines could be disconnected, leaving the engines to run as smaller compounds at cruising speeds. A somewhat similar arrangement is in use on the "Nashville," where the large cylinder of a quadruple expansion engine can be thrown out, leaving a triple expansion for lower powers. The objection to all of these is that, if it becomes necessary in an emergency to get full power, it is often impossible to stop to couple up. This was exemplified in a marked way in the case of the "Brooklyn" during the fight at Santiago. She was cruising with her after engines only when Cervera's fleet came out, and it was felt that there was not time to stop to couple up, which would have necessitated from twenty minutes to half an hour. The distribution of the power among more than two shafts offers another solution, which was used on the "Columbia" and "Minneapolis." Personally, I believe that this system, if properly carried

out, would be entirely satisfactory, but it would involve the use of the center screw only for ordinary cruising, and a ship, as you doubtless know, is not so handy with one screw as with two. Our latest design to meet the desire to use two screws and still get relatively small engines for cruising speeds is to use three screws but make the engine driving the center one half the total power, leaving each of the wing screws to develop only a quarter of the full power. We have not as yet built any vessels on this plan, so that, while theoretically we have every reason to anticipate entire success, it has not as yet been tried in practice.

A very interesting illustration of the application of ingenuity and scientific knowledge is the method adopted for balancing the engines so as to avoid vibration of the hull. As engine speeds and hull dimensions increased, there came a combination of circumstances causing excessive vibration of the hull due to unbalanced inertia stresses of the reciprocating parts of the engines. The solution is a very simple adaptation of a type of engine desirable for other reasons with a special arrangement of crank angles and weights of reciprocating parts. The adoption of the steam turbine has also been suggested to accomplish this same object, and turbines have been employed on some torpedo boats. With certain very promising features, there are, however, some great disadvantages, and before the steam turbine becomes a formidable rival of the ordinary type of engine an enormous amount of skill and ingenuity must be exercised, and the lines along which they can act are not yet apparent.

I have already referred to the three vital elements in warship design as offense, defense and mobility, and the best combinations of these features to secure maximum results tax the judgment and experience of the designer, as well as his skill and ingenuity. If time permitted, it would be of the greatest interest to show how the necessity of maximum results in particular items has given us special classes of vessels. Thus in the battleship, which must give and take heavy blows, mobility or speed has been sacrificed, while in the armored cruiser both guns and armor have

been reduced to secure high speed. In the torpedo boat, speed is absolutely vital and everything else is sacrificed to it. The tendency just now seems to be along the line of having only one class of armored vessels which will be very powerful armored cruisers with good armor protection and high speed. This means a vessel of about 12,000 to 14,000 tons displacement, with 8 to 10 inches of Krupp armor, a battery of 10-inch rapid-fire guns, and a speed of about twenty to twenty-one knots.

We have now given a hasty glance at the principal elements of the modern war vessel, although I regret that the limited time at my command has forbidden the consideration of many features which could not have failed to be of interest to you, such as the workshops on board where the necessary routine repairs are made to keep the great machine in working order; the electric installation for lighting the various portions of the ship and providing the searchlights; the elaborate drainage system with the necessary pumps; and the torpedoes, with their wonderfully intricate and delicate machinery, which is so arranged as to work automatically after being discharged from the ship, in a way that would seem to indicate human control at every moment. I trust, however, that you will have heard enough to satisfy you that the theme of my remarks is fully borne out by the facts which have been adduced.

The truth is that in every department of life there has been a tremendous advance, due to the exercise of skill, ingenuity and scientific knowledge, with which the modern war vessel has thoroughly kept pace. A moment's reflection would, of course, make it very clear to us that it would be impossible to build war vessels such as we now possess unless there had been a corresponding development in every other manufacturing industry. Governor Roosevelt, when Assistant Secretary of the Navy, touched upon a very important matter connected with this subject in discussing what was known as the "Personnel Bill." In comparing the development of naval science to the point where it became necessary for every officer in the navy to be an engineer, so that it is necessary for the modern admiral to

know many things of which our great Farragut, for example, was ignorant, he said that it would, of course, require vastly greater skill to handle the complicated mechanism which the modern war vessel is, than one of the old ones, but that, just as we had always been able to produce competent men to handle the less complicated vessels of former times, so without doubt we would get competent men to handle those of to-day. He had learned the fact that the modern warship is a vast engine, and to be properly controlled must be handled by engineers. Congress has in the Personnel Bill provided and directed that, as soon as we can make the necessary arrangements, every officer in the navy charged with the handling of a vessel shall be a trained engineer, and therefore we may be sure that however complicated and delicate the organisms of the machine become, we shall have officers who, by education and experience, are fitted to properly care for the valuable and delicate machines entrusted to them.

I have had a part in two wars, in both of which the navy played an important part and became dear to the people, and I have also passed through the intervening interval, during much of which the navy seemed to be entirely forgotten. I sincerely trust that, as the late war showed we know not only how to build good ships, but also to make them go and to fight them, our fellow-citizens in civil life will see to it that the navy is maintained in a state of the highest efficiency, both as to personnel and material, ever ready for efficient use when needed. In this work, which on both sides is a matter for engineers, this Institute has a vital interest, and I trust that, just as your influence has for seventy-five years been on the side of the general advancement of engineering in the mechanic arts, so it will be on the side of their advancement in the navy.

THE PRESSING OF STEEL; WITH ESPECIAL REFERENCE TO ECONOMY IN TRANSPORTATION. (LOSS.)

DISCUSSION.

(*Concluded from page 40.*)

MR. LOSS:—In replying to the criticisms of Messrs. Christie and Lewis, I desire to say that their main argument referring to the small power necessary for punching as compared to that required for shearing—all as indicated by the experiments—is one that demands careful attention and thought.

When the first efforts showed up this extraordinary result, I could not myself believe their correctness, and in my desire to find the truth, I discarded the entire operating mechanism, building in its stead a complete new device; but the results were identical.

It is difficult to analyze the flow in punching. There is a very distinct side movement of the particles of the metal before any direct severing takes place. This fact was established some years ago by Messrs. Hoopes and Townsend, of Philadelphia, when punching 1¾ inches thick material with a ½-inch punch, resulting in a punching of a thickness of 1⅛ inch. The major part of the difference represented side flow. For thinner plates this flow is proportionately very much less, but it still exists.

And again, the quicker the punching process, the less is the flow and the greater is the power required.

Taking it all in all, I am exceedingly glad that these results have been laid before the Institute, as I feel sure that the careful investigation which this subject will now receive from its members will result in establishing the absolute truth, whatever this may be.

It is gratifying to find Mr. Lewis corroborating me in my assertion that *practical* shear is after all only resistance to flexure.

Regarding his reference to the relation between energy and thickness of plate in punching, let me simply state that

the indicator cards were marked as they are, independently of any positive assumed relations.

These particular experiments were just recently made, and hence any mathematical deduction had not as yet been undertaken.

Referring to the greater energy required in shearing with flat knives as compared to the results from those having the blades set at an angle, the indicator cards are all so unanimous as to leave no doubt about this general law.

The greater ultimate with the flat knife is sufficient to more than make up for the shorter cutting stroke made by this particular knife, as compared to the beveled one.

The power required to shear a rectangular bar with flat knives varies directly with the thickness. Of this there is no doubt. As to my reasons for the formula for the ultimate for steel angles, I shall simply refer to my article on this subject in *The American Engineer and Railroad Journal*, May, 1893, where it is covered fully. There is, however, a certain unknown factor connected with this particular part of my work, but whether right or wrong, an intelligent discussion requires the consideration of the data given in the above-mentioned article.

As truly said by Mr. Lewis, any one of the detailed subjects considered here to-night could form a profitable topic for an evening's discussion, and I sincerely trust that my fellow-members of the Institute will help and co-operate with me in the work which I have undertaken, and which to date has been only partly completed.

ERRATA.—JOURNAL FRANKLIN INSTITUTE (December, 1899).

Page 462, line 35, for "six to seven," *read* eight to ten.

Page 465, line 24, for "2,500°," *read* 1,800° to 2,000°.

Page 465, line 27, for "1,800°," *read* 1,400° to 1,600°.

Page 467, line 33, for "2 inches," *read* 1½ inches.

Page 467, line 37, for "Energy per square inch," *read* Energy in foot-pounds per inch of width of bar.

Page 468, in table at top of page, for "inch-pounds," *read* foot-pounds.

Page 468, first line of text, for "2," *read* 1½.

Page 468, paragraph 3, for "The energy per square inch in foot-pounds," *read* The total energy in foot-pounds.

Page 472, line 6, for "our work," *read* the works of The Pressed Steel Car Company.

ICE BREAKERS IN POLAR EXPLORATION.

By Edwin Swift Balch.

Polar exploration, if divided in accordance with the ships employed, may be classified into three periods. The first covers four centuries, from the great voyage in 1596 of the pioneer, Willem Barentz, of Holland, to the building of the "Fram." During this period, ships were almost defenseless against the Arctic ice, and when they were pushed into it, they practically lost all means of independent locomotion, even after the advent of steam. They would be crushed or stay on top, in accordance with the movements of the ice, and in utter disregard of the wishes of the men on board. Curiously enough, however, no one seems to have given any thought to the models of ships for polar exploration. Any old ship was considered suitable for the purpose, after she had received some extra strengthening. Whaling and sealing vessels were not constructed on the best lines to resist ice pressure, for their main object was to permit the stowage of large quantities of oil. Experience gradually fostered the belief that no ship could be devised strong enough to resist a real pressure from the ice in the winter months, even if it might be fortunate enough to escape in the summer ones.

The second period begins and ends with the voyage of the "Fram." This reversed all previous notions on the subject, and proved conclusively that a ship can be built of sufficient defensive power against ice floes, to drift in safety across the Arctic Ocean. The "Fram" was designed * with the idea of making "the shape of the hull such as to offer as small a vulnerable target as possible to the attacks of the ice;" and to build her "so solidly as to be able to withstand the greatest possible pressure from without in any direction whatever." To accomplish these aims, she was

* "Farthest North," by F. Nansen, Vol. I.

built with extremely sloping sides, which enabled her to rise in response to every increase of ice pressure. When the pressure became great, the "Fram" was lifted by the ice and rode on top of it; until, with a diminution of the pressure, the weight of the ship caused her to settle down again.

The third period may be said to begin with an address delivered some time in 1898, before the Russian Geographical Society, by Vice-Admiral Makaroff, of the Imperial Russian Navy, in which he proposed to reach the pole by means of ice breakers. An abstract of his paper was published in the *Geographical Journal* for October, 1898. He succeeded in having a large ice breaker built, not for Arctic travelling, but for commercial purposes, and the story of this ice breaker is told at length in the *Geographical Journal* for January, 1900.

The "Yermak" was built in England by Armstrong, Whitworth & Co., according to the designs of Admiral Makaroff. She was intended to clear the way in winter time through the ice to the port of St. Petersburg, and in summer time to help the navigation to the Siberian rivers flowing into the Kara Sea, barricaded by ice almost during the whole summer. She is a steel ship, with a double bottom and double sides, and is divided into forty-eight compartments. She is 305 feet long, and 71 feet broad. With 3,000 tons of coal aboard, her displacement is 8,000 tons, and in this condition she draws 25 feet. Her bow is inclined 70° from the vertical; her stern is 65°, and her sides are 20° from the vertical. In whichever direction she moves in the ice, she is bound to rise on it and break it with her weight. She has four engines, working four independent propellers, one in front and three at the stern. Each engine develops 2,500 horse-power, so that the total force of the engines is 10,000 horse-power. Each propeller is supplied with an extra auxiliary engine, so that the main engine can be disconnected if necessary; this was meant to save fuel under certain conditions.

The "Yermak's" maiden voyage was from Newcastle to St. Petersburg in the winter time, on which occasion she

forced her way with ease through 160 miles of ice. In June, 1899, under the command of Admiral Makaroff, she was given a trial in the polar ice west of Spitsbergen. After this, she steamed back to Newcastle, where she was strengthened and the forward propeller taken out. On August 6th, she again entered the polar ice north of Spitsbergen. This time she was in the ice two weeks, "covering in that period 230 miles in eighty-seven hours."

No attempt was made at exploration, although it is believed that land was discovered to the northeast, as evidenced by the refraction of the air. The time was devoted to studying the ice, the ship herself, and her behavior in the ice. The trip was, in fact, a shipbuilder's trial trip. In heavy ice, where there was considerable pressure, it took four hours to make 2 miles. In moderately thick ice, the ship made 2½ miles or more an hour. It was found that the conditions of the ice were so different in the Baltic and in the Arctic, that to get the best results in the latter, a special ship would have to be constructed. Admiral Makaroff came to the conclusion that strength of construction was the main point and that even the "Yermak" was not strong enough, but that the engine power could be reduced without disadvantage; in fact, he thought 2,500 horse-power would be sufficient for fairly good progress through the ice. The room gained by reducing engine power could be utilized to carry more fuel, and about this it was also concluded that liquid fuel would be preferable in all respects to coal.

These experimental voyages of the "Yermak" prove conclusively, what was never suspected before, that a vessel may be constructed of sufficient offensive power and sufficient defensive power to force her way through the Arctic pack. The problem of how to penetrate the unknown regions of the Arctic and of the Antarctic appears solved at last. It means discarding the old methods of wooden vessels, sledges, dogs, etc., wherever the sea extends and adopting the resources of the modern naval engineer, of steel, steam and electricity. The change is complete, and the results may prove a lasting benefit to scientific geography.

Franklin Institute.

(Proceedings of the annual meeting held Wednesday, January 17, 1900.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 17, 1900.

President JOHN BIRKINBINE in the chair.

Present, 92 members and visitors.

Additions to membership since last report, 18.

The annual reports of the Board of Managers and of the several committees were presented and accepted. (See Appendix.)

Mr. Daniel Baugh was elected to fill the vacancy in the Board of Managers caused by the resignation of George Vaux, Jr.

The Rev. Henry C. McCook, D.D., was elected as an honorary member of the Institute, on the recommendation of the Board of Managers.

A letter was read by the Secretary from Hon. Abram S. Hewitt, acknowledging his election as an honorary member of the Institute.

The tellers of the annual election reported the votes cast at the election; whereupon the President declared the following gentlemen elected to the offices for which they were nominated, viz.:

For President	(to serve one year)	JOHN BIRKINBINE.
" *Vice-President*	(" three years)	THEO. D. RAND.
" *Secretary*	(" one year)	WM. H. WAHL.
" *Treasurer*	(" ")	SAMUEL SARTAIN.
" *Auditor*	(" three years)	WM. O. GRIGGS.

For *Managers* (to serve three years).

ARTHUR BEARDSLEY,	H. W. JAYNE,
HENRY C. BROLASKY,	LAWRENCE T. PAUL,
JAMES CHRISTIE,	HORACE PETTIT,
F. LYNWOOD GARRISON,	OTTO C. WOLF.

For *Members of the Committee on Science and the Arts* (to serve three years).

HENRY F. COLVIN,	JOHN M. HARTMAN,	LOUIS E. LEVY,
THOS. P. CONARD,	CHAS. C. HEYL,	TINIUS OLSEN,
GEO. S. CULLEN,	H. R. HEYL,	LUCIEN E. PICOLET,
CHAS. DAY,	GEO. A. HOADLEY,	GEO. F. STRADLING,
ARTHUR FALKENAU,	HARRY F. KELLER,	W. F. WILLCOX.

Mr. Birkinbine made a communication on "The Engineering Features of the National Export Exposition," which was substantially an informal report on the work involved in the designing and erection of the buildings of the exposition, the details and installation of the power and transmission plant, water supply, lighting and electric service.

Messrs. A. M. Greene, Jr., and C. O. C. Billberg supplemented the President's remarks with explanations relating to the last-named features of the work.

Mr. Wm. E. Quimby, of New York, described and illustrated, with the aid of lantern projections, the construction and operation of the "Screw Pump," which he had devised as a rotary pressure pump. The communication was discussed by Messrs. Fullerton, Eppelsheimer, the President and the speaker.

On motion, the subject was referred to the Committee on Science and the Arts for investigation.

Mr. Arthur Kitson exhibited several of the most recently improved forms of his incandescent oil lamps, and made some explanations respecting their efficiency and practicability in service.

Adjourned.

WM. H. WAHL, *Secretary.*

APPENDIX.

ANNUAL REPORT OF THE BOARD OF MANAGERS OF THE FRANKLIN INSTITUTE.

[For the year 1899.]

To the Members of the Franklin Institute.

GENTLEMEN:—In presenting its report of the work of the Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, the Board of Managers congratulates the members upon the substantial evidences of progress, and urges continued co-operation to advance the Institute.

Every committee has been active, and the work accomplished by some of these has done much to advance the work in which the Institute is engaged. The sections have, with generous rivalry, endeavored to excel in the character of papers presented, the discussions upon them, and the renown of those invited to participate in their meetings.

Three new sections were added during the year 1899, and sectional work appears to be a proper method for increasing the usefulness of the Institute, by giving the members the opportunities for close association in special lines of technical work for mutual benefit.

The membership roll has substantially increased, principally through non-resident accessions. Our membership now represents that of a national body —a unique condition for an organization having a permanent local home. In accomplishing this result, the Committee on Membership has been most persistent.

The popular lecture courses provided by the Committee on Instruction have, judging from the audiences drawn to them, proven eminently satisfactory.

The efforts of the Curators to add to the comfort of the members and improve the building have been handicapped by the necessity of deriving revenue from a portion of the building. An effort is being made to remove some of the objections.

Notwithstanding the fact that some of the income from invested funds was not available, the Library makes a better exhibit in respect of additions

than the previous year. This is the Institute's most valuable asset, and it is entitled to receive the most cordial support from our members and friends.

The Library will, in the future, enjoy the benefit of two new funds—that of the late M. Carey Lea and the James T. Morris fund, founded by John T. Morris. Serious consideration is being given to the making of provision for a proper place and arrangement of the large and valuable pamphlet collections, which, up to the present, are practically useless.

The adoption of the book-stack system has proven generally satisfactory, and has also shown its great advantage over the old plan in the preservation of the orderly arrangement of the books.

The Institute has established in the past year a school of instruction in Naval Architecture, which has met with gratifying success, and promises well for the future. If these hopes are realized, its scope will presently be extended to embrace classes in Marine Engineering. The Board considers this departure, in aid of the great and growing shipbuilding interests of the city, as a most important one.

The older schools of Drawing and Mathematics are well sustained, and make a better showing than for several years past.

The Committee on Endowment has prosecuted its work, but has not succeeded in securing the amount desired, the numerous demands upon those able to aid in this effort having hampered the work. The Committee hopes, however, with the assistance of the Institute's members, to accomplish the task which it has attempted.

Two occasions made the year 1899 memorable in the Institute's history. The first of these was the active co-operation of the Franklin Institute and the Philadelphia Museums in the National Export Exposition, held from September 16th to December 2d, which was quite successful. The Department of Awards was conducted by members of the Institute, and the medals and diplomas given will aid in making known the Franklin Institute and its work. The other occasion of importance was the celebration of the founding of the Franklin Institute, which consisted of a public recognition, at the proper date, February 5th, and a Memorial Sermon by Rev. Henry C. McCook, D.D., supplemented by a series of important meetings held in the National Export Exposition Buildings, October 2d to 7th. To each of the sections of the Institute was assigned a part of an evening, and to the Institute, the final session. At these meetings a series of papers of unusually high order were presented by men who are recognized as authorities in their respective specialties.

The proceedings of the seventy-fifth anniversary week will be published, with some incidental historical matter, in the form of a separate "Memorial Volume," which is now being compiled by the Secretary.

During the year the Institute was also recognized by its President serving, by invitation, as a member of the committee to unveil the statue of Benjamin Franklin presented to the city of Philadelphia by Mr. Justus C. Strawbridge.

The Franklin Institute has passed its seventy-fifth year. Its next notable anniversary will mark a century of useful work. What the Institute will be in 1924 will depend largely upon the membership of to-day. It is probable that a majority of those now on the rolls will have passed away before the Institute is one hundred years old, but each of us may do his or her part

towards making the future as memorable as the past, by maintaining the present activity, and giving to the work our best endeavors and our personal interest.

There is much to encourage in the record of the past years; there is much to be done in the years to come.

The record of membership, the resources, liabilities, receipts and expenditures, the details of the work of committees of the Institute and of the Board, also those of the Committee on Science and the Arts, and the reports of the various sections, are appended for the information of members.

By order of the Board.

JOHN BIRKINBINE,
President.

PHILADELPHIA, January 10, 1900.

MEMBERS.

Members at the close of 1898	1,850	
Number of new members elected who have paid their dues in 1899	389	
		2,239
Lost by death, resignation and non-payment of dues,		88
Total membership at the end of 1899		2,151

FINANCIAL STATEMENT FOR THE YEAR 1899.

Balance on hand January 1, 1899	$62 62
Receipts from all sources	18,609 88
	$18,672 50
Payments for all accounts	18,564 69
Balance	$107 81

ENDOWMENT FUNDS.

The Permanent Endowment Funds of the Institute, at the end of 1899, consist of the following:

(In the hands of the Institute.)

Bloomfield H. Moore Memorial Fund	$15,000 00	
Memorial Library Fund	1,000 00	
B. H. Bartol Fund	1,000 00	
Amount received from Life Memberships between January 1, 1891, and October 1, 1894	1,755 00	
		$18,755 00

Brought forward		$18,755 00
(In the hands of Elliott-Cresson Trustees.)		
*The Elliott-Cresson Medal Fund (approximate)		4,729 55
(In the hands of the Board of Trustees of the Franklin Institute.)		
The Legacy of George S. Pepper	$38,562 50	
The Legacy of Eugene Nugent	1,000 00	
Legacy of Emeline B. Nicholson	1,520 00	
The Edward Longstreth Medal Fund	1,000 00	
The Donation of an Unknown Friend	5 00	
The Donation of Sigmund Riefler	20 00	
Life Membership Fund since October 1, 1894	1,750 00	
Journal Endowment Fund	138 00	
Special Endowment Fund	1,105 00	
James T. Morris Memorial Fund	1,000 00	
By the will of John Turner, deceased, one-fourth of net income on 2 per cent. of his residuary estate, yielding about $100 or more per year, equivalent to a capital sum of	2,000 00	
		48,100 50
		$71,585 05

*Figures for 1899 are not at present accessible. Last year's amount is therefore substituted.

ANNUAL REPORT OF THE COMMITTEE ON INSTRUCTION, 1899

To the Board of Managers of the Franklin Institute.

GENTLEMEN:—The Committee on Instruction is able to report that the same arrangements respecting its popular lectures as have been in operation for several years, with the co-operation of the Young Men's Christian Association, have remained in force, and that the outcome has proved mutually beneficial and satisfactory. The Committee has been able, as in former years, to secure the voluntary services of a number of distinguished lecturers, whose co-operation in contributing to the work of the Institute should be recognized by a suitable expression of thanks.

The very large attendance of members at these popular lectures has fully demonstrated that they meet a demand which the Institute is justified in recognizing even at greater cost than they now entail. Also, the problem of the differentiation of the popular from the strictly technical work of the Institute, now conducted successfully through the sections, is thus satisfactorily solved, and without friction.

As to the school work, the Committee may report substantial progress during the past year.

The number of pupils attending the Drawing School was 231, showing an increase, as compared with the previous year, of forty-five.

Thirty pupils were enrolled in the Mathematical School, which may be said to have only come into active existence in 1899. The outlook for this school is considered to be distinctly encouraging.

The experiment was made last year of aiding in the organization of a School of Naval Architecture, on the strong representations of Mr. Chas. H. Cramp that a school of this kind, under the patronage of the Institute should prove highly beneficial to the many apprentices and young men engaged in shipyards in and about Philadelphia. The undertaking has thus far amply justified this opinion. Although it has been in operation but a few months, there were enrolled at the close of the year thirty-six pupils. Should the participation of pupils continue to grow in accordance with expectations, the scope of the school will, in time, be extended to embrace the allied subject of Marine Engineering.

The Committee desires here to express its appreciation of the zealous and efficient work of the Directors in charge of the schools.

WM. H. WAHL, *Chairman.*

ANNUAL REPORT OF THE COMMITTEE ON THE LIBRARY FOR THE YEAR 1899.

To the President and Members of the Franklin Institute.

GENTLEMEN :—The Committee on the Library respectfully reports the following summary of the operations of the Library during the year 1899 :

	Bd. Vols.	Unbd. Vols.	Pphs.	Chts.	Lithogr.
Additions—By Gift	764	318	1957	3	1
From Com. on Pub.	25	9	5		
Moore Fund	143	20	37	4	
Mem'l Library Fund		2			
General Fund		1			
Lea Fund	13	1			
Binding	268				
Exchange	15				
	1,228	351	1,999	7	1

Total additions for the year 3,586

An increase of 660 over 1897 and 749 over 1898.

Total number of volumes January 1, 1900 50,348

Total number of pamphlets January 1, 1900 35,545

The Library also contains 2,807 maps and charts, 642 designs and drawings, 1,222 photographs, 191 newspaper clippings, 26 manuscripts.

Binding—Periodicals, reported among the additions . . . . . 268 vols.

Old Books	10 "
Moore Fund Books	6 "
Memorial Library Books	3 "
Rebound	1 "
Repaired	5 "
	293

Exchanges.—Four hundred and eighty-seven societies and publications were on the exchange list of the *Journal* during the year 1899, an increase of twenty-eight over 1898.

The Library, in its new fire-proof steel stack, has been open with great satisfaction and continuously throughout the year. But the entire satisfaction is short-lived, for the increased numbers of public documents that are coming to the Library make it evident that during the coming year already there will be lack of room for proper accommodation. The British patent collection also is growing so rapidly that it is impossible to give shelf-room to the last two shipments received. Moreover, the 35,500 and odd pamphlets, an extremely valuable part of the Library, still lie practically useless without shelving in the third story of the part of our building that is not fire-proof.

Two plans have been proposed for obtaining the additional accommodation so pressingly required, and as they are both so inexpensive, only needing an outlay of a few hundred dollars, your Committee strongly urges that both may be authorized. One of the two plans was urged in our last annual report, namely, the use of one of the two front rooms on the lower floor of the building. That room has now been vacated by the former tenant, and, even if it should be desired to use it for the Institute purposes, the walls would give place for a considerable number of volumes or pamphlets. The other plan is to add another story to the book stack itself, by cutting off the Seventh Street end of the present drawing school.

Proper accommodation for the invaluable collection of drawings and charts is still lacking, as reported last year.

The binding has been continued, and if the appropriation of the past year for the purpose can be renewed the coming year, and if, at the same time, the unexpended balance of last year's appropriation can also be used, very satisfactory progress can be accomplished.

The main addition of books has been, as in former years, from special gifts during the year, and next from the volumes of serials received in exchange for the *Journal*.

The older book funds, the Moore Fund, about $750 a year, and the Memorial Library Fund, about $50 a year, have supplied a smaller number of volumes than usual. The Mathew Carey Lea Fund, amounting to about $150 a year, has now just begun to add its quota. The James T. Morris Fund has, by the liberality of Mr. John T. Morris, just been doubled, that is, increased to $2,000, and is expected to yield about $100 a year, and to begin to be usable at once.

The Library Committee has worked zealously and harmoniously, with well-attended, spirited meetings. Different branches of applied science are now represented on the Committee, but all have mutual consideration for the claims of the others, and aim at the filling out of a well-balanced library.

BENJ. SMITH LYMAN,
Chairman Library Committee.

PHILADELPHIA, January 8, 1900.

ANNUAL REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS, 1899.

To the President and Members of the Franklin Institute.

GENTLEMEN:—The statistics of the operations of the Committee on Science and the Arts for the year 1899, herewith appended, present a highly

creditable record of the Committee's activity during the past year. Its comparison with the records for the year immediately preceding appears distinctly favorable and encouraging, as evidenced by the following general summaries:

Cases pending at the beginning of the year:

1898	32
1899	42

New cases from all sources:

1898	59
1899	56

Cases finished during the year:

1898	47
1899	63

Cases pending at the close of the year:

1898	44
1899	35

Thus, the number of cases pending was one-third greater at the beginning of the past year, and one-fifth less at its close than the corresponding statistics of the year before.

Again, the number of investigations completed was one-third greater for 1899 than for 1898.

The number of medals awarded, of all classes, presents a like aggregate, namely, ten, although the Elliott Cresson Medal was not conferred in a single instance during the year just closed.

In view of the numerous cases that are now being referred to this Committee by the Bureau of Awards of the National Export Exposition, it may confidently be expected, apart from other reasons, that the Committee is now entering upon one of the most fruitful years of its honorable existence.

In closing his connection with the Committee, in the relation of its presiding officer, the Chairman desires to express his appreciation of the courteous consideration extended to him at all times, and his personal thanks to the Secretary for his valuable and efficient aid, always cheerfully rendered.

EDGAR MARBURG,
Chairman Committee on Science and the Arts.

ANNUAL REPORT OF THE COMMITTEE ON MEETINGS FOR THE YEAR 1899.

To the President and Members of the Franklin Institute.

GENTLEMEN:—The Committee on Meetings has held regular sessions as prescribed by the by-laws, and has arranged for the presentation of nineteen communications. Of these, a number have appeared in the *Journal*, and others have been deemed sufficiently interesting to warrant their reference to the Committee on Science and the Arts.

The attendance at the stated meetings during the past year has shown

some improvement, indicating the maintenance of interest on the part of the membership.

Respectfully submitted, on behalf of the Committee,

WASHINGTON JONES,
Chairman.

PHILADELPHIA, January 10, 1900.

ANNUAL REPORT OF THE COMMITTEE ON SECTIONAL ARRANGEMENTS, 1899.

To the Board of Managers of the Franklin Institute.

GENTLEMEN:—In transmitting to the Board of Managers the annual reports of the several sections, the Committee on Sectional Arrangements desires to express its gratification that the policy to which the Institute has lately committed itself, of establishing sections for the benefit of its members as rapidly as the need for them became apparent, has demonstrated its utility in the most unmistakable manner.

Following closely upon the organization of the Mining and Metallurgical Section in 1898, two new sections were founded in 1899—the Mechanical and Engineering Section and the Physical and Astronomical Section; and the Chemical Section found it desirable to extend the scope of its operations by the formation of a Photographic and Microscopic Branch, which, to all intents and purposes, represents a third new section set in operation during the past year.

The large number of members who have attached themselves to these new centers of activity in the Institute, and the very general interest manifested in their meetings, furnish the best evidence that could be desired to prove that the members of the Institute are prompt to avail themselves of the opportunities afforded by the new sections to meet for mutual benefit.

Every new department thus established strongly adds to the advantages which the Institute affords to its members, and enlarges the scope and value of its work as a technical society, and the Institute has reason to be well satisfied with its progress in this direction during the past year.

Several projects for new sections have been under advisement for some time, but on account of the diversion of interest and attention to the conduct of the Exposition, they have not been pressed to realization. During the present year, however, your Committee confidently expects that they will be carried into effect.

The Institute has now in active operation five sections, viz.: Chemical Section, Electrical Section, Mining and Metallurgical Section, Mechanical and Engineering Section, and Physical and Astronomical Section. All of the older sections show substantial gains in membership, and all exhibit a degree of activity that promises well for the future.

The Committee has heretofore expressed the desirability of attracting a larger number of young men toward the Institute, and with that intent, the grade of Junior Associates was created; and the subjects discussed before the Mechanical Section have usually been popular and attractive in style. This project has not been fully developed, and it is believed it could be extended by a personal canvass. Possibly the creation of a section especially devoted

to the interests of the Juniors might be useful, as a similar system has proved highly effective with the engineering societies in New York.

The Committee would recommend this project for the consideration of the Board, as it is believed to offer a most promising field for the future usefulness of the Institute.

JAMES CHRISTIE, *Chairman.*

January 5, 1900.

ANNUAL REPORT OF THE CHEMICAL SECTION, 1899.

To the Committee on Sectional Arrangements.

GENTLEMEN:—The Chemical Section has maintained an unimpaired activity during the past year. Meetings have been held regularly, and the papers and discussions presented, of which the more important have appeared in the *Journal*, were fully up to the standard of the work previously done by the Section.

During the past year the need for affording the members an opportunity of cultivating certain collateral branches of science caused the Section to expand its facilities by the creation of a branch devoted to photography and microscopy, which has maintained a creditable state of efficiency.

The combined membership of the Section and the Branch, at the close of the year, is 162.

The Section held an interesting joint meeting at Bethlehem, Pa., in May, with the Lehigh Valley Branch of the American Chemical Society.

The Section also participated actively in the ceremonies attending the celebration of the seventy-fifth anniversary of the Institute.

The Institute is now beginning to realize the income of the Lea Fund, for the purchase of books relating to chemistry and physics, and the Section last year recommended to the Library Committee the purchase of a number of valuable reference works with the available income, in accordance with the committee's action requesting the Section's aid in the premises.

The list of authors, and the titles of communications presented and subjects discussed at the meetings of the Section and the Photographic and Microscopic Branch, are hereto appended.

"Methods for the Examination of Explosives." Dr. W. J. Williams.

"The Clarification and Purification of Municipal Water Supplies." Mr. Allen Hazen.

"A Process for Testing Metals." Mr. Joseph Richards.

"The Laboratory Production of Asphalts from Animal and Vegetable Matters." Dr. Wm. C. Day.

"The Development of Pneumatic Chemistry." Dr. H. C. Bolton.

"On Series in Spectra." Prof. E. A. Partridge.

"The Use of Iron in the Purification of Water." Dr. Thos. M. Drown.

"The Two-Circle Goniometer." Dr. Joseph W. Richards.

"A Historical Sketch of Methods for the Liquefaction of Gases." Dr. H. F. Keller.

"Artificial Graphite." Dr. Wm. H. Wahl.

"The Relations of Chemistry to the Progress of the Arts." Dr. Harvey W. Wiley (Anniversary Address).

"The Influence of Science in Modern Beer Brewing." Dr. Francis Wyatt.

"Artesian Waters." Dr. Henry Leffmann and Mr. Lewis Woolman.

"An Improved Stereoscopic Camera." Mr. John G. Baker.

"The Systematic Application of the Microscope to the Detection of Adulterations of Food" (discussion).

"The Making of Photography." Dr. Chas. F. Himes (Anniversary Address).

"The McDonough Process of Color Photography." Mr. Frank V. Chambers.

"The Organization of Photographic Record Work" (discussion).

"An Improved Device for Holding Squeegee and other Dry Plates in Mounting." Mr. John G. Baker.

Exhibition of Accessories to the Microscope, including, especially, the Polariscope and Spectroscope.

JOSEPH W. RICHARDS,
President.

ANNUAL REPORT OF THE ELECTRICAL SECTION, 1899.

To the Committee on Sectional Arrangements.

GENTLEMEN:—The Electrical Section has had a successful year, if interest in, and attendance on its meetings, is any criterion.

The membership at the beginning of the year was 116; and at the present date it is 140, showing a gain of twenty-four for the year.

Not only have there been interesting papers for each meeting, but also the members have shown their interest in them by vigorous discussion.

The papers read at the meetings have been as follows: Meeting of January 20, 1899, W. H. Tapley, of the United States Government Printing Office, at Washington, D. C., "Practical Application of the Electrical Motor to Printing Press Machinery." February 28th, demonstration evening, Prof. W. S. Franklin, of Lehigh University, showed and described some forms of the Nernst Lamp that he had made; he also showed that heated glass is an electrical conductor by sending a current of 2,000 volts A. C. through a glass tube after heating it with a Bunsen burner. The current resulting from this voltage melted the tube.

Mr. Elmer G. Willyoung showed the construction and operation of the electrolytic interrupter, in connection with a coil and X-ray tube. Mr. Balderston, of Williams, Brown & Earle, exhibited a new form of static X-ray machine in operation.

March 28th.—Mr. Frank Sprague, of New York, "The Multiple Unit System of Electric Traction."

Mr. Albert B. Herrick, of New York, "The Electrical Inspection of Street Car Equipment."

Mr. Edward E. Higgins, of New York, "Some of the Transportation Problems in Larger Cities."

Mr. Charles Hewitt, of the Union Traction Company, of Philadelphia, opened the discussion on the preceding papers.

April 25, 1899.—Prof. R. A. Fessenden, Western University of Pennsylvania, Alleghany, Pa., "The Design of Electro-Magnetic Mechanism."

Prof. J. Henry Klinck, of Lehigh University, Pa., "A Photometric Comparison of Illuminating Globes."

May 19th.—Mr. Jas. Hamblet, of New York, "Electric Clocks Historically Considered, and the Uniform Distribution of Time." Mr. J. D. Darling, of Philadelphia, showed an improved form of primary battery (Harrison cell).

July 20th.—In place of the regular meeting at the Institute an excursion to Lincoln Park, by boat, was attended by about thirty members.

October 3d.—At the National Export Exposition, in honor of the seventy-fifth anniversary of the Franklin Institute, addresses were delivered as follows:

Dr. Edwin J. Houston, "The Seventy-fifth Anniversary from an Electrical Standpoint." (Anniversary Address.)

Mr. Ralph W. Pope, of New York, "Influence of Technical Societies in Promoting the Progress of the Electrical Arts." (Anniversary Address.)

November 24th.—Mr. F. W. Willcox, of the General Electric Company, Harrison, N. J., "Incandescent Lamps and Filaments." Mr. Walter E. Harrington, Camden, N. J., "Rail Bonding."

December 22d.—Discussion of the subject "Automobiles" by Messrs. Morris, Salom, Marks and Roche.

In conclusion, I wish to congratulate the Section on its prosperous condition and its opportunities for future growth and activity. I wish also to express my personal appreciation of the efficient work of the Program Committee, to whom, more than to any one else, the success of the year is due.

GEO. A. HOADLEY,
President of the Electrical Section.

REPORT OF THE MINING AND METALLURGICAL SECTION, 1899.

To the Committee on Sectional Arrangements.

GENTLEMEN:—The Mining and Metallurgical Section has to report, in connection with its operations during the past year, a substantial gain in general interest in its work on the part of its members.

There were presented during the year 1899, fourteen papers, some of a high order of excellence, and all of interest.

The membership at the close of the year is eighty-six.

The Section took an active part, as the representative of the Institute, in the work of the International Association for Testing Materials, having named a committee of five members to act in its behalf in furthering the objects of the Association. This committee also took an active part in the work of the American Branch of the Association, which is now well advanced.

In May, the Section united with the Chemical Section in a joint meeting with the Lehigh Valley Branch of the American Chemical Society, held in Bethlehem, Pa. The event proved to be one of much interest, embracing a visit of inspection to the works of the Bethlehem Iron Company, the Government Ordnance Works and the Lehigh University.

The program of the Section for the current year is filled for the greater portion of the meetings, and the general character of the papers to be offered is such as will fully sustain the reputation of the Section as a live and growing branch of the parent tree.

Appended hereto is a list of papers read in 1899:

"Segregation in Steel Ingots." Mr. A. W. Allen.

"The Mogollon (N. M.) Mining District." Dr. H. M. Chance.

"The History of Malleable Cast Iron Manufacture in the United States." Mr. George C. Davis.

"Klondike Region." Professor Angelo Heilprin.

"Iron Ores of the Oural Mountains." Mr. H. B. C. Nitze.

"Notes on the Reduction of Iron Ores." Mr. John M. Hartman.

"Subterranean Ice Deposits." Mr. Edwin S. Balch.

"Titaniferous Iron Ores." Prof. J. F. Kemp.

"Some Features in the Structural Design of Buildings." Prof. W. H. Burr.

"Riddles Wrought in Iron and Steel." Mr. Paul Kreuzpointner.

"The Development of the Iron Manufacture in the United States." Mr. John Fritz (Seventy-fifth Anniversary Address).

"Three-quarters of a Century's Progress in Mining and Metallurgy." Mr. Charles Kirchhoff (Seventy-fifth Anniversary Address).

"The Annealing of White Cast Iron." Mr. Chas. James.

"The Tilly Foster Mine." Mr. Edward K. Landis.

"Some Modern Methods of Deep Mining." Dr. H. M. Chance.

JAMES CHRISTIE,
President.

ANNUAL REPORT OF THE MECHANICAL AND ENGINEERING SECTION, 1899.

To the Committee on Sectional Arrangements.

GENTLEMEN:—Although the Mechanical and Engineering Section may be said to have only entered upon its career at the beginning of the year 1899, its brief history has abundantly confirmed the excellent judgment of its founders, not only by the circumstance that its membership is considerably larger than that of any of the other coördinate branches of the Institute, but also by the large attendance at its meetings and the very general interest which these meetings have attracted.

The policy adopted by the Section from the beginning of its career was, as far as possible, to avoid formality and to promote and encourage the free interchange of opinion among its members, with the view thereby of insuring the active participation of the large number of mechanics in the membership of the Institute, whose interests it was felt by the organizers of the Section should be considered as paramount to all other objects.

To interest this class of its members, the Section wisely decided from the start to devote its meetings largely to the discussion of debatable subjects of importance to mechanical experts, and to invite the freest discussion of them by the members and others. The wisdom of this policy has been abundantly confirmed.

The following subjects were discussed during the year at the Section meetings:

"Travelling Cranes."

"The Mechanical Applications of Compressed Air."

"Internal Combustion Engines."

"The Construction, Operation and Maintenance of Pumping Machinery."

"Hydraulic Transmission, Valves and Packing."

In addition to these, the Section devoted two meetings to the presentation of the following communications:

"An Engineer's Experience on the United States Repair Ship 'Vulcan,' with Admiral Sampson's Fleet," by Prof. Wm. S. Aldrich; and a paper on "The Flow of Steel," by Mr. Henrik V. Loss.

The Section also participated in the ceremonies of the celebration of the seventy-fifth Anniversary of the Institute, in the Convention Hall of the National Export Exposition, on which occasion the President made an introductory address, and was followed by Dr. Coleman Sellers, who gave an admirable address on "The Progress of the Mechanical Arts in Three-quarters of a Century."

The membership of the Section at the close of the year 1899 is 192, and with the gratifying results already attained, it is confidently hoped and believed that in this Section a new and important field of usefulness has been added to the Franklin Institute, which will continue to grow and yield an abundant harvest.

WILFRED LEWIS, *President.*

ANNUAL REPORT OF THE PHYSICAL AND ASTRONOMICAL SECTION, 1899.

To the Committee on Sectional Arrangements.

GENTLEMEN:—The Physical and Astronomical Section was organized on February 8, 1899, on the petition of eighteen members of the Institute.

On May 19th, following, the inaugural meeting was held in the lecture-room, in the presence of a large and interested audience of members and friends. The proceedings embraced an inaugural address by Professor Cleveland Abbe, of the U. S. Weather Bureau, "On the Relation of the Mechanic Arts to Physics and Astronomy." Addresses were also made on the occasion by Dr. A. E. Kennelly, President of the Section; Prof. T. C. Mendenhall, President of the Worcester Polytechnic Institute, Worcester, Mass.; Prof. A. S. Mackenzie, of Bryn Mawr College, Bryn Mawr, Pa.; Prof. L. d'Auria, and others.

The Section has since held regular monthly meetings, as prescribed by the by-laws of the Institute, at each of which one or several communications of interest have been presented and discussed.

A list of these is appended hereto.

The organization of a section of the Institute devoted to pure science emphasizes in the most convincing manner the recognition which the Institute has always given to the fact that all the advances made in the arts have their origin in the cultivation of science for its own sake by original investigation, and exemplifies that union of "science with practice" which it has ever been the aim of the Franklin Institute to represent.

The list of communications presented at the meetings held in 1899 is as follows:

"Methods of Determining the Gravitation Constant." Prof. A. S. Mackenzie.

"The Daguerreotype and the Action of Light upon Silver Iodide." Dr. E. A. Partridge.

"The Florentine Enigma." Dr. G. B. M. Zerr.

Introductory Address, Seventy-fifth Anniversary Celebration. Dr. A. E. Kennelly.

"Some Notable Contributions of American Physicists during the last Three-quarters of a Century" (Anniversary Address). Dr. T. C. Mendenhall.

"Loudness of Sound." Dr. Geo. F. Stradling.

"The Coördinates of the Center and Radius of a Circle and the Angle of Intersection of Two Circles in Trilinear Coördinates." Mr. Jesse Pawling, Jr.

"The Aberration Constant." Dr. G. B. M. Zerr.

A. E. KENNELLY, *President*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of the proceedings of the stated meeting held Wednesday, January 3, 1900.*]

PROF. EDGAR MARBURG in the chair.

The following reports were adopted:

Graphophone "Grand."—Thomas N. Macdonald, Bridgeport, Conn.

The subject of this investigation is a modification of, and improvement upon, the graphophone, a method and apparatus for recording and reproducing sounds, invented by Chichester A. Bell and Sumner Tainter, of Washington, D. C. The report embraces a historical summary of the evolution of sound recording and reproducing machines, and a scientific analysis of the modes of operation of the several types of these machines.

The report is reserved for publication *in extenso*.

The investigators award to Mr. Macdonald a Certificate of Merit, and to Messrs. Bell and Tainter they recommend the award of the John Scott Legacy Premium and Medal. [*Sub-Committee.*—Louis E. Levy, Chairman; J. M. Emanuel, H. R. Heyl, Samuel Sartain.]

Levy's Acid-Blast Process of Etching Metal Plates.—Louis E. Levy, Philadelphia.

ABSTRACT.—The invention consists in the application of an atomized spray of acid or other eroding agent, which is projected vertically upward by means of an air-blast against the surface to be etched, and in a certain combination of appliances for effecting this object.

The invention is covered by letters-patent in various countries, those of the United States bearing date of October 12, 1898.

For details of the method and apparatus reference is made to this *Journal*, **147**, 337. (ART. Levy—"Acid-blast Process for Etching.")

The inventor has made several improvements in details since the reading of his paper before the Institute, at the stated meeting of February 15, 1899, the most notable of these relating to the making of efficient provision for preventing the heating of the plate and the acid during the etching operation.

The report finds that the claims of the applicant respecting the several advantages of the process are substantially correct, and after an examination of

all accessible records, the conclusion is stated that the process and apparatus are original with him, and in view of the importance of this invention, and in consideration of the originality of the idea and of the ingenuity displayed in its application, the award of the Elliott Cresson Medal is recommended. [*Sub-Committee.*—Frank E. Manning, Chairman; George H. Buchanan, Samuel Sartain.]

The following reports were considered:

System of Oil Heating and Incandescent Lighting.—Arthur Kitson, Philadelphia.

Water Heater for Range Boilers.—Adam Heller, Baltimore, Md.

Pneumatic System for Preventing the Bursting of Water Pipes.—N. Monroe Hopkins, Washington, D. C.

Braiding Machine.—Andrew V. Groupe, Philadelphia.

These were held under advisement.

SECTIONS.

PHOTOGRAPHIC AND MICROSCOPIC BRANCH (CHEMICAL SECTION).—*Stated Meeting*, Tuesday, January 2, 1900. Dr. Leffmann in the chair.

Mr. John G. Baker described an apparatus and method which he had devised for entitling negatives, and exhibited several lantern slides to demonstrate the utility of the invention. The subject was discussed by Messrs. Sartain, Ives, Leffmann and the author.

The subject announced for discussion, namely, "Micro-photography and Photo-micrography," was then announced by the chairman, who defined the proper significance of these terms, which are frequently, but improperly, used interchangeably. The distinction was emphasized by the exhibition of specimens. Special attention was called to the utility of micro-photography as a means of preserving, in convenient, transportable form, valuable and bulky records, manuscripts, etc.

A recess was taken to permit of the inspection of the exhibits with the aid of the projecting lantern and table microscope. The discussion was participated in by Messrs. Keeley, Baker, Ives and Leffmann.

The Executive Committee, to which had been referred the question of the reorganization of the branch as an independent Section, reported in favor of the change, and was authorized to carry the proposition into effect, in co-operation with the parent section. W.

PHYSICAL AND ASTRONOMICAL SECTION.—*Stated Meeting*, Friday, January 5, 1900. Prof. L. D'Auria in the chair.

The following communications were presented and discussed:

"The Co-ordinates of the Center and Radius of a Circle, and the Angle of Intersection of Two Circles in Trilinear Co-ordinates." By Jesse Pawling, Jr., and the "Aberration Constant." By Prof. G. B. M. Zerr.

The following officers were elected for the current year: President, Dr. A. E. Kennelly; Vice-Presidents, Prof. L. D'Auria and Prof. Geo. F. Stradling; Secretary, Prof. E. A. Partridge; Conservator, Dr. Wm. H. Wahl. W.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, January 10, 1900. Mr. James Christie in the chair.

Prof. F. Lynwood Garrison read a paper on "The Lead and Zinc Ores of Southwestern Missouri." The author devoted his attention specially to the lead and zinc deposits in the region commonly known as the Joplin district. He described their geological relationships, and dwelt at length on the topographical and other surface indications by which the presence of the ores is supposed to be shown. The paper concluded with a general historical sketch of the development of this mining district, the methods in vogue for the mining and treatment of the ores, statistics of production, etc. The paper was well illustrated with the aid of ore specimens, lantern slides and diagrams. Some discussion followed.

The following officers were elected for the current year: President, Mr. Joseph Richards; Vice-Presidents, Dr. D. K. Tuttle and Mr. A. E. Outerbridge, Jr.; Secretary, Mr. G. H. Clamer; Conservator, Dr. Wm. H. Wahl. W.

MECHANICAL AND ENGINEERING SECTION.—*Stated Meeting*, Thursday, January 11, 1900. Dr. Wahl in the chair.

The subject for discussion was "The Heating and Ventilation of Workshops and Factories." Opened by Mr. Walter B. Snow, of Boston.

Mr. Snow described, and very freely illustrated, with the aid of the lantern, the blower system, as applied in its most modern aspects to industrial establishments and other large buildings.

An animated discussion followed.

The election of officers was postponed until the next stated meeting. W.

CHEMICAL SECTION.—*Stated Meeting*, January 16, 1900. Dr. W. J. Williams in the chair.

Prof. Robt. H. Bradbury presented a paper on "Racemism," which was an elaborate *résumé* of the present scientific views entertained on this highly interesting subject.

A report was presented by Dr. Keller, for the special committee named to consider the proposition of the Photographic and Microscopic Branch to sever its connection with the Section and form an independent section. The report favored the change.

The following officers were elected for the current year: President, Dr. W. J. Williams; Vice-Presidents, Mr. Lyman F. Kebler and Mr. Joseph Richards; Secretary, Mr. Wm. H. Ridenour; Conservator, Dr. Wahl.

A vote of thanks was extended to Dr. Joseph W. Richards, the retiring President, for his zeal and ability in the Section's interest during his term of office. W.

ELECTRICAL SECTION.—*Stated Meeting*, January 23, 1900. Mr. C. J. Reed in the chair.

The following officers were elected for the current year: President, Prof. W. S. Franklin; Vice-Presidents, Messrs. Joseph Richards and Geo. T. Eyanson; Secretary, Mr. Richard L. Binder.

The paper of the evening was read by Prof. John Price Jackson, State College, Pennsylvania, on "Electrical Machinery for Use in Coal Mining." The subject was profusely illustrated by means of lantern slides.

The thanks of the meeting were tendered to the speaker.

Adjourned. W.